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ABSTRACT

This document presents a transcript of the hearing to examine undergraduate science education in relation to the traditional and nontraditional sources of future research scientists. Two specific aspects of the topic were identified for examination: (1) successful methods of science education employed at small liberal arts schools; and (2) what can be done to increase participation of underrepresented groups in science. The Subcommittee heard testimony from 10 witnesses representing small colleges successful in producing mathematics and science majors and in increasing the participation of underrepresented groups in science. Testimony: (1) highlighted aspects of the Project Kaleidoscope report; (2) pointed out the poor state of science and mathematics education in the United States today and discussed four initiatives for undergraduate studies that might help rectify that situation; (3) cited the apprenticeship model of education and the work ethic of traditional small liberal arts college students as reasons for their success in supplying future scientists; (4) attributed the success of undergraduate institutions in developing future scientists to the participation of the students in undergraduate research that stimulates student interest in science; (5) discussed undergraduate and minority high school student research projects that contribute to the interest in science careers; (6) discussed the contributions of historically black colleges in providing future scientists; (7) discussed strategies to attract members of underrepresented groups into science; (8) addressed the issues of recruitment and retention of women in science; (9) discussed collaborative efforts with universities and schools to attract girls and minorities into science; and (10) discussed the National Science Foundation's role in Project Kaleidoscope. Prepared statements and other supplemental materials submitted by the witnesses are included. (MDH)

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TRADITIONAL AND NONTRADITIONAL SOURCES OF FUTURE RESEARCH SCIENTISTS

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HEARING

BEFORE THE

SUBCOMMITTEE ON
INVESTIGATIONS AND OVERSIGHT

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED SECOND CONGRESS

FIRST SESSION

JULY 11, 1991

[No. 59]

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TRADITIONAL AND NONTRADITIONAL SOURCES OF FUTURE RESEARCH SCIENTISTS

THURSDAY, JULY 11, 1991

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Investigations and Oversight,
Washington, DC.

The committee met, pursuant to notice, at 9:30 a.m., in room 2325, Rayburn House Office Building, the Hon. Howard Wolpe (Chairman of the subcommittee) presiding.

Mr. Wolpe. The hearing will come to order.

Today the Subcommittee on Investigations and Oversight will examine undergraduate science education as we look at traditional and nontraditional sources of future research scientists. There are few today that need to be convinced of the desperate state of science and math education at all levels in this country. We simply are not producing a sufficient number of students in science, and those we are producing often do not have a quality science education.

Now, more than ever, science and math education are vital to the future of our country. Quality science education is necessary to provide the professional and technical expertise critical to the continued advancements in such fields as health care, energy, economic competitiveness and environmental protection. In addition, we must enable our country's citizens to deal responsibly with an increasingly technical society.

The Science Committee, of course, has had a longstanding interest in science education. In recent years, the Science Committee has held numerous hearings and enacted legislation on various aspects of science, math and engineering education at all levels: pre-college, technical, undergraduate, and graduate. Our revitalized efforts at all these levels are important.

Undergraduate schools are strategically positioned to impact both pre-college and graduate education. Undergraduate schools supply outstanding students to graduate science programs. They can also improve pre-college science education by supplying better qualified teachers.

The undergraduate years represent a crucial time in a student's education, since it is during the undergraduate years that future scientists, college faculty, and teachers are recruited and educated.

In this hearing, in order to provide some focus, we will examine two specific aspects of undergraduate science education. First, we will look at successful methods of science education employed at

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the small liberal arts schools, which traditionally have been sources of outstanding science undergraduates.

These predominantly undergraduate schools produce math and science baccalaureates at a rate which is three times that of the national average. Graduates of these schools go on to earn Ph.D.s in math and science at a rate over twice the national average.

At a time of declining science enrollment, it is imperative that we support and expand vital undergraduate science efforts such as those found at these colleges.

Secondly, we want to learn what can be done to increase the participation of underrepresented groups in science. These underrepresented groups, which include African Americans, Hispanics, Native Americans, and women, are nontraditional sources of science students. By failing to draw adequately on these groups, we are losing out on a growing pool of diverse talent.

Testimony today will highlight the recently-released Project Kaleidoscope report, which addresses these two aspects of undergraduate science education. Project Kaleidoscope is an in-depth study designed to analyze and make recommendations on strengthening undergraduate science and math education. The study was funded in part by a grant from the National Science Foundation and in part by private foundations, including the Kellogg Foundation.

The Project Kaleidoscope report recognizes the leadership role the NSF has played in setting priorities for undergraduate education. Certainly, the NSF has a number of commendable programs addressing this issue. However, in light of the troubled nature of science and math education, we must question whether current efforts are sufficient.

Project Kaleidoscope is the most recent, but certainly not the only, report of this nature to have appeared on undergraduate science education. The goal of this hearing is not simply to hear about yet another report and its recommendations, but instead to come away from this hearing with a concrete plan of action for urgently-needed changes in policies and programs to strengthen undergraduate science education. Such an action plan will be directed towards NSF initiatives, since it is the NSF that must take the lead in this area.

Before turning to our opening statements this morning, I want to express my concern about the attitude of certain officials of the National Science Foundation who have responded rather defensively in recent days to legitimate oversight activities of this subcommittee.

Specifically, I refer to questions that the subcommittee has raised with the NSF about management of the Research in Undergraduate Institutions program. This is a subject that has been actually highlighted in the Project Kaleidoscope report. It is highlighted in the testimony of several of the witnesses we will be hearing from today.

When we learned from one of these witnesses that NSF had abolished its office for managing RUI, the subcommittee immediately sought information from the Foundation on the status of RUI. Although the Foundation did supply us with some documentation on this decision, documentation which we will be reviewing later this morning, one NSF official had a very different reaction.

Dr. Joe Danek called subcommittee staff, not to discuss a substantive policy management question, but rather to probe whether the subcommittee learned of these changes from an NSF employee.

Although as I said earlier, we learned of this matter from our own witnesses, I am very disturbed by Dr. Danek's response, which seemed aimed at cutting off communication between the committee and NSF on a subject which the committee has had a longstanding interest. He seemed more concerned with this bureaucratically defensive mentality, rather than solving the problem that is the subject of this inquiry today.

I will be raising this matter later with Dr. Williams of the Foundation when he testifies on behalf of the Foundation. I want to receive his assurance at that point that free and open communication between the committee and NSF personnel will in fact be respected and protected.

[The prepared opening statement of Mr. Wolpe follows:]

OPENING STATEMENT OF REP. HOWARD WOLPE

JULY 11, 1991

Good morning, I welcome all of you to this morning's hearing. Today, the Subcommittee on Investigations and Oversight will examine undergraduate science education as we look at Traditional and Non-traditional Sources of Future Research Scientists.

I don't need to convince this audience of the desperate state of science and math education at all levels in this country. We are not producing sufficient numbers of students in science, and those we are producing often do not have a quality science education.

Now, more than ever, science and math education are vital to the future of our country. Quality science education is necessary to provide the professional and technical expertise critical to continued advancements in such fields as health care, energy, economic competitiveness, and environmental protection. In addition, we must enable our country's citizens to deal responsibily with an increasingly technical society.

The Science Committee has of course had a long-standing interest in science education. In recent years, the Science Committee has held numerous hearings and passed legislation on various aspects of science, math, and engineering education at all levels: precollege, technical, undergraduate, and graduate. While revitalized efforts at all of these levels are important, undergraduate schools are strategically positioned to impact both precollege and graduate education. Undergraduate schools supply outstanding students to graduate science programs; they can also improve precollege science education by supplying better qualified teachers. The undergraduate years represent a crucial time in a student's education since it is during the undergraduate years that future scientists, college faculty, and teachers are recruited and educated.

In this hearing, in order to focus in some detail on concrete recommendations for actions, we will narrow the very broad topic of science education to examine two specific aspects of undergraduate science education.

First, we will look at successful methods of science education employed at the small, liberal arts schools, which traditionally have been sources of outstanding science undergraduates. These predominantly undergraduate schools produce math and science baccalaureates at a rate which is three times that of the national average. Graduates of these schools go on to earn Ph.D.'s in math and science at a rate over twice the national average.

In a time of declining science enrollment, it is imperative that we support and expand vital undergraduate science efforts such as those found at these colleges.

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We are looking forward to exploring this issue with the experts we have invited here today and using their insights to formulate specific recommendations for actions to strengthen undergraduate science education.

Before we move on to other opening statements, I must express my concern about the attitude of certain officials of the National Science Foundation, who have been very defensive about legitimate oversight activities of this Subcommittee in recent days.

Specifically, I refer to questions that the Subcommittee has about management of the RUI (Research in Undergraduate Institutions) program. Project Kaleidoscope highlighted the importance of this program. So does the testimony of several of our witnesses today. When we learned from one of these witnesses that NSF had abolished its office for managing RUI, the Subcommittee immediately sought information from the Foundation on the status of RUI. Although the Foundation did supply us with some documentation on this decision -- documentation which we will be reviewing later this morning -- one NSF official had a very different reaction. Dr. Joe Danek called Subcommittee staff not to discuss a substantive policy and management question, but to probe whether the Subcommittee learned of these changes from an NSF employee. Although, as I said earlier, we learned of this matter from our witnesses, I am very disturbed by Dr. Danek's response, which seemed aimed at cutting off communication between the Committee and NSF on a subject on which the Committee has had a longstanding interest.

I will raise this issue later this morning with Dr. Williams of the Foundation. I want to get his assurance that free and open communication between the Committee and NSF personnel will be respected and protected.

Mr. **Wolpe.** I should indicate that—you have heard the bells just now—we have a rather important Democratic caucus taking place this morning. After I offer an opportunity to Mr. Nagle and Mr. Sensenbrenner to make any opening remarks they might care to make by way of opening statements——

Mr. **Sensenbrenner.** I have no opening statement.

Mr. **Wolpe.** Mr. Nagle?

Mr. **Nagle.** I have no opening statement.

Mr. **Wolpe.** In a moment, then, I will be recessing the hearing to allow the Democratic members to record their votes in a quorum. We will not await the conclusion of the caucus, we will be getting the hearing underway in 10 or 15 minutes. But we will have to recess one more time to allow us to record our votes in the leadership race that is taking place this morning.

With that, I think the best thing to do would be to actually recess at this point, and we will be returning momentarily.

[Recess.]

Mr. **Wolpe.** The hearing will resume. I would like to invite our first panel of witnesses to come forward to the table.

Our first panel will present the findings and recommendations of Project Kaleidoscope with regard to undergraduate science education at the small liberal arts schools. In this hearing we would like to find out from this panel how these schools produce such a high percentage and high quality of science and math graduates, and how some of these strategies might be adopted at other schools.

We also hope to learn how to make Federal efforts, especially those of the National Science Foundation, more effective in promoting the programs of these institutions.

We will be hearing from Dr. Daniel Sullivan, President of Allegheny College in Meadville, Pennsylvania. He served as Chair of the Executive Committee for Project Kaleidoscope. He will be followed by Dr. Timothy Light, President of Middlebury College in the State of Vermont.

Our next witness will be Dr. Michael Doyle, Professor of Chemistry at Trinity University in San Antonio, Texas, and a Founder of the Council on Undergraduate Research, the Editor of the Council on Undergraduate Research Newsletter, and a member of the Project Kaleidoscope Advisory Committee.

I will reserve introduction of our last panelist, Dr. James Swartz, for Congressman Nagle, who will be returning very shortly.

As you know, in order not to prejudice any past or future witnesses, it is the policy of the committee to swear all witnesses in. Does anybody have any objection to being sworn in? If not, will you all please stand and raise your right hand.

[Witnesses sworn.]

Mr. **Wolpe.** I want to remind all the witnesses that because of time constraints we are asking that everyone stay within the five-minute time frame for their oral presentations. Your entire written statements will be entered into the record, of course. But in light of the large number of witnesses we will be hearing from today, it is important that we try to stick to that time limit in order to provide sufficient time for questions.

We also have a little timer here which will ding in a little less intrusive way than my pounding the gavel on you, but we hope when you hear the ding you will conclude your remarks.

Without objection, there will be photographs taken at this hearing.

With that, let me invite our first witness, Dr. Sullivan, to begin his testimony.

TESTIMONY OF DR. DANIEL F. SULLIVAN, PRESIDENT, ALLEGHENY COLLEGE, MEADVILLE, PA; CHAIR, PROJECT KALEIDOSCOPE EXECUTIVE COMMITTEE

Dr. **Sullivan**. Mr. Chairman, members of the Subcommittee, my name is Dr. Daniel F. Sullivan. I am President of Allegheny College in Meadville, Pennsylvania. I am pleased to have this opportunity to speak to you about Project Kaleidoscope.

For the past two years, I have served as Chair of the Executive Committee of Project Kaleidoscope which, as you indicated is a National Science Foundation sponsored panel of college presidents, academic deans, and faculty from liberal arts colleges all across the country, convened to identify what works in science and mathematics education and to recommend an action plan for reform of the undergraduate portion of our badly underperforming system of science and mathematics education in America.

Our report, "What Works: Building Natural Science Communities," was presented to Dr. Walter Massey of the National Science Foundation exactly one month ago. I have summarized its essential conclusions in the written testimony in advance of this hearing. The report speaks powerfully to the issues on your agenda today. I would be happy to discuss any and all parts of it in response to your questions.

What is not in the report, and what I would like to focus on is how the issue of quality science and math education looks to the president of a liberal arts college, and in particular how involvement of a college like mine with the NSF leads over time to stronger and stronger teaching and learning in science and math.

We know that what works in science and math education is learning that is hands-on, active, investigative and experiential, where the curriculum is rich in laboratory experiences, steeped in the methods of scientific research as it is practiced by professional scientists, and where students and faculty work together in the learning community.

This kind of science and math education does not just happen, as is obvious from its absence in so many undergraduate institutions. It must be consciously sought and planned for by faculty and administrators. There must be a vision and a plan pursued over a great many years. Presidential leadership and commitment is vital.

One of the most critical kinds of presidential leadership involves linking the college with its local concerns and needs to national resources and needs. The National Science Foundation is for our colleges perhaps the most significant national resource, not just through the funding it provides, but more importantly through the ongoing peer review which results from participating in its grant competitions.

Let me illustrate with this past year's experience at Allegheny. We were fortunate this year to receive funding for four of the five proposals we submitted to NSF under the Instrumentation and Laboratory Improvement Program, ILI. One of these funded proposals, involving the introduction of a laboratory method of teaching calculus allowed us to equip an additional laboratory with a cluster of NEXT workstations. Next year, all calculus teaching at Allegheny will take place in hands-on laboratories, where faculty will act essentially as coaches rather than lecturers.

We have learned through several years of experimentation that this approach succeeds better with our students than traditional forms of mathematics teaching.

But this proposal took three years to be successful in the NSF competition. The first year involved exploratory conversations with NSF staff, who taught us where the research front is nationally with respect to this kind of teaching innovation, and put us in touch with key people at other institutions.

In the second year, we submitted our first proposal and were unsuccessful. However, the feedback on our proposal brought our faculty into closer contact with where the action is nationally. We were learning all the time, innovations from other institutions were diffused and tested against our own experience, and our approach was improved and refined.

The equipment money we have received for our successful second attempt is terrific. The long-term impact of being brought into the club in this area of mathematics pedagogy will in my judgment be even greater.

The NSF undergraduate education programs do this over and over with a large number of institutions, each receiving a handful of relatively small grants. It is the primary way NSF exerts a form of leadership and enters into a partnership deeply respectful of local campus dynamics.

The NSF, after all, cannot do science and math education for us, and it cannot just tell us what to do. But it can and does exert significant leverage in support of a theory of science and math education on which there is now a strong national consensus, by reinforcing thoughtful local initiatives.

We at Allegheny have benefitted in this way, not just from the ILI program, but from NSF grants supporting our efforts to introduce a focus on science and math teaching preparation into our existing teacher preparation program and from a major NSF facilities grant that has allowed us to renovate completely our psychology laboratories. In each case, engagement with the peer review process was like commissioning an external departmental program review.

In my view, existing practice and existing programs in undergraduate science and math education within NSF are pretty close to the mark. For the most part, the right programs are in place. They remain significantly underfunded.

There is occasionally the temptation to seek grand global models and solutions by funding huge demonstration projects at a small number of institutions. I believe such an approach is a snare and a delusion.

Just as active learning is what we wish our students to experience, so do we support and encourage active learning on the part of the faculty at the incredibly diverse undergraduate institutions that make up America's higher education landscape.

I would be pleased, as I indicated, to respond to the questions of the subcommittee about the Project Kaleidoscope report and respectfully thank you for inviting us here to speak with you.

[The prepared statement of Dr. Sullivan follows:]

STATEMENT

to the

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

U. S. HOUSE OF REPRESENTATIVES

July 11, 1991 Hearing on
"Traditional and Nontraditional Sources of Future Research Scientists"

by

Dr. Daniel F. Sullivan
President, Allegheny College, Meadville, Pennsylvania

On behalf of:

Project Kaleidoscope
Associated Colleges of the Midwest
Great Lakes Colleges Association
Central Pennsylvania Consortium

In Association with:

The Independent Colleges Office

Mr. Chairman and Members of the Subcommittee: My name is Dr. Daniel F. Sullivan. I am President of Allegheny College in Meadville, Pennsylvania, and I am pleased to have this opportunity to speak to you on behalf of Allegheny College, our sister institutions within the Associated Colleges of the Midwest (ACM), the Great Lakes Colleges Association (GLCA), the Central Pennsylvania Consortium (CPC), and Project Kaleidoscope.

For the past two years I have served as Chair of the Executive Committee of Project Kaleidoscope, a National Science Foundation-sponsored panel of college presidents, academic deans, and faculty convened to identify what works in science and mathematics education and to recommend an action plan for reform of the undergraduate portion of our badly underperforming system of science and mathematics education in America. Our report, "What Works: Building Natural Science Communities," was presented to Dr. Walter Massey of the National Science Foundation exactly one month ago. The report speaks powerfully to the theme of this hearing, "Traditional and Nontraditional Sources of Future Research Scientists."

It is important to note right at the outset, Mr. Chairman and Members of the Subcommittee, that Project Kaleidoscope came into being at the initiative of the National Science Foundation. Kaleidoscope is an example of a growing recognition by NSF that its powerful and visible leadership, not just its money for research and education, must be brought to bear if our performance as a nation in science and mathematics is to improve. We need the NSF to take a strong role in setting the benchmarks for quality in science and mathematics education, and to pull the community together in order to move forward systematically. We need the colleges and universities of America to acknowledge their responsibility to be essential partners in the national effort to address the challenges we face in science and mathematics. The colleges are prepared to play their role; we know the NSF is committed to playing its essential role.

The NSF has come a long way since the disastrous science education policies of the early 1980s. Interagency coordination of science and mathematics education policy, under the auspices of the Committee on Education and Human Resources of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), has perhaps never been better. For the most part, the right programs are in place. In crucial respects, they remain significantly underfunded, making the task of improving science and mathematics education for all Americans a difficult one.

We know from dozens of reports and studies during the past six years that this nation has deep-seated problems of equity, quality, and quantity in science and mathematics education:

- There is an alarmingly low level of scientific and technological literacy in the general population.

- There is a projected critical shortage of well-educated scientists, mathematicians and engineers.

- There are severe inequities in the access of minorities and women to science and mathematics fields.

Several indicators show clearly the distressing state of science and mathematics education in America:

- National assessments show that only about 7% of U.S. adults and 20% of college graduates are literate in science.

- The number of entering college freshmen planning to major in one of the physical sciences declined by 61% in 16 years, from 7.3% in 1967 to 2.4% in 1983, and since that time the percentage has remained level.

- The percentages of Ph.D.'s in mathematical and physical sciences awarded to Americans has declined significantly in the last thirty years. These percentages are now less than 70% in the physical sciences, 50% in mathematics, and 45% in engineering.

- Whereas Blacks comprise 12% of the population, they receive only 4% of the science and engineering baccalaureates and 2% of the doctorates.

It is clear from these and other data that U.S. science and mathematics education is underperforming seriously.

In Project Kaleidoscope we focused our attention on a group of colleges -- the liberal arts colleges of America -- where the pattern is remarkably different from the national data. We sought to understand what works in these colleges, and then formulated a national action plan based on our understanding.

Carnegie classification Liberal Arts I colleges outperform all other Carnegie categories in the production of science and mathematics majors and graduates who achieve a Ph.D. in science or mathematics.

The first point that needs to be made -- and made emphatically -- is that the nation's liberal arts colleges, especially the 140 colleges in Carnegie Classification Liberal Arts I, are major players in the production of scientists and mathematicians. As institutions we are typically small in size, but our commitment to a well-rounded education -- including significant exposure to natural science and mathematics -- and our approach to teaching, attract and keep students in science and mathematics. The facts are these:

- Over the past thirty years America's liberal arts colleges have produced science and mathematics baccalaureates at a rate over three times the national average. With only 3% of the nation's undergraduate enrollment, Liberal Arts I institutions award 10% of the nation's total baccalaureate degrees in the natural sciences and mathematics. This 10% equates to an absolute number of science and mathematics baccalaureates that is greater than the number produced by Carnegie Classification Research I Universities, the nation's top research universities. It is not uncommon to find liberal arts colleges graduating more majors in science or mathematics than nearby universities that are ten times larger. At my own college -- Allegheny -- and over a fifty year span of time, 25% of graduating seniors have majored in a natural science or mathematics field, and in several years in the last decade we graduated more chemistry majors than all of Penn State University.

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- Compared to all other types of colleges and universities, liberal arts colleges are also high producers of women, Black and Hispanic natural science and mathematics baccalaureates.

- Graduates of the liberal arts colleges earn Ph.D.'s in science and mathematics at over twice the national average (twelve per thousand as compared to six per thousand on average), and their women graduates earn science and mathematics Ph.D.'s at a rate higher than is the case for other college and university categories.

- In my state, Pennsylvania, 15% of the baccalaureate degrees are awarded by independent liberal arts colleges, but 19% of the degrees in science and mathematics are earned by liberal arts college graduates; 31% of the Ph.D.'s in science or mathematics earned by graduates of Pennsylvania colleges or universities are earned by liberal arts college graduates; and 47% of the graduates of Pennsylvania colleges or universities in the National Academy of Sciences earned their degrees at Pennsylvania liberal arts colleges.

The record is clear. Something special happens to science and mathematics students in the nation's liberal arts colleges. These colleges are a pump rather than a filter in the scientific manpower pipeline. Liberal arts institutions need to be at the table when science education policy is made. We have much to contribute to the solution of America's underperformance in science and mathematics.

What accounts for the differential productivity of the liberal arts colleges in science and mathematics? The purpose of Project Kaleidoscope was to answer just that question -- to discover and clearly communicate what works in science and mathematics education.

What works is learning that is active, hands-on, investigative, and experiential, where the curriculum is rich in laboratory experiences, steeped in the methods of scientific research as it is practiced by professional scientists, and where students and faculty work together in a learning community.

Liberal arts colleges are places where teaching and research come together in practice as well as in theory, where senior professors are actively engaged in classroom and laboratory teaching, and where the commitment to teaching is supported by institutional procedures related to hiring, tenure, and promotion. They are distinguished by educational environments that offer students small classes and regular study groups. Many of these institutions offer students plentiful opportunities to work one-on-one with faculty, a curriculum that strives to be lean but lab-rich, and abundant opportunities for hands-on research. Because of their traditions, size, and lack of bureaucracy, these institutions can serve as testing grounds for new approaches to teaching and learning: they have flexible curricula and faculty who break away from established disciplinary norms.

The Best Science Courses are Investigative

The best college science courses, from introductory to advanced levels, are conceived and run in a partially investigative mode. Investigation, the natural arena for using and solidifying one's knowledge, may be manifest in open-ended laboratory and library projects or in small research projects made available to students. The personal and social attributes of learning science in an investigative mode extend to the whole of the student's experience. Having professors in undergraduate laboratories -- all Allegheny science faculty teach introductory science courses with laboratories, for example -- means that they get to know their students and their capabilities exceedingly well. This close contact is important in the process of becoming a scientist.

Full Access to College Facilities and Resources is Essential

In liberal arts colleges students typically have access to science libraries, computers, laboratories, instruments, class materials, study areas, and class and seminar rooms twenty-four hours a day, seven days a week. The great pedagogical payoff of having a science building occupied and used by students at all hours is that they develop a learning community. Advanced students help beginners learn how to function efficiently; the student network disperses knowledge of where materials are, how instruments work, what is in the library, how to use computers, and who is expert on what. Most importantly, students receive the kind of feedback that engenders the confidence and inquisitiveness of a secure identity.

The Curriculum Should Be Lean and Lab-Rich

Science as practiced in liberal arts colleges is generally lean in number of courses offered and in formal requirements for the major. A student aspiring to a career tied to the major will fulfill requirements for that career as interest quickens. The crucial thing is to get the student to start aspiring, to enter on the process of learning the discipline. This end is best served by introductory courses that involve investigation and by streamlined requirements for the major; elaborate majors that anticipate every contingency by requiring arrays of lock-step courses are recipes for depopulated departments. Faculty in liberal arts colleges generally concentrate, therefore, on making a limited number of courses superb, well-integrated, and important rather than laboring to create a varied menu of courses that provide an exhaustive survey of the discipline.

In summary, science instruction at liberal arts colleges is a case of "less being more." There is less formal content in the curriculum, less total expertise and specialization in the faculty, and perhaps fewer holdings in the library and the instrument rooms. There is, however, more exposure of students to real science: to the research-like modes of taking initiative, figuring things out, working with others, asking questions and discussing, making things work, using the library, and thinking and writing critically about procedures and results. Science learning in liberal arts colleges is more frequently active learning, not passive learning. That is why more of our students begin and complete major studies in science and mathematics.

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Given this understanding of what works in undergraduate science and mathematics education, what initiatives must receive the highest priority in the next five years? Project Kaleidoscope recommends four critical initiatives, each of which requires active commitment and leadership on the part of the National Science Foundation, oversight of which is the responsibility of this subcommittee of the House Committee on Science, Space, and Technology.

Where to start: initiatives which must receive the highest priority in the next five years.

INITIATIVE 1. REFORMING THE INTRODUCTORY COURSES IN UNDERGRADUATE SCIENCE AND MATHEMATICS.

***Recommendation #1**: The FY 1983 NSF Budget Request for Instructional Laboratory Equipment be increased to $33 million, with a continuing focus on introductory courses.

***Recommendation #2**: The FY 1993 NSF Budget Request for Course and Curriculum Development include an $18 million outlay for local improvements in introductory courses at colleges and universities, in addition to the outlay for comprehensive programs.

***Recommendation #3**: These programs be housed, along with their budget authority, within USEME, with an administrative structure that addresses the need to coordinate programs and policies with the research directorates.

The transformation of introductory courses must be NSF's highest undergraduate priority over the next five years. A significant body of research and our own experience confirms that the first year of college is the point of a critical drop-off in numbers of students in science and mathematics courses.

Students acquire and confirm lifelong beliefs and attitudes about science and mathematics in their introductory courses. This is where they make the decision whether or not to major in these fields, whether or not to take further courses, whether or not it is important to be literate on science issues. When these courses are dull, consisting mainly of lectures and canned labs, when they keep students isolated and passive, and press on at breakneck speed for the sake of "coverage," when they are too big and faculty members are unwilling to support each student's progress, they slam the door on the positive attitudes toward science. The final formal experience of learning science is often one of frustration and failure. Courses labeled introductory turn out to be terminal.

Our own experience validates that the introductory course can be a pump instead of a filter. Introductory courses can give first-year students the pleasure of discovery and the opportunity to construct personal understanding of science and mathematics at a critical stage in their academic career.

The recommended funding levels given above are consistent with those in the Neal Report; they address the demonstrated interest at the local level to strengthen undergraduate programs, and they establish a more equitable balance in NSF support for research and education programs.

Several hundred proposals, requesting over $200 million, were submitted to NSF for the first competition of the expanded Course and Curriculum Program, excluding proposals in Calculus and Engineering. The available funds through USEME, for all disciplines, was $14 million. A similar level of interest is evident in the Instructional Laboratory Improvement (ILI) program, where each year proposals reviewed request almost four times the funds available from NSF. We are particularly concerned that the College Science Improvement Program (CSIP) -- the ILI component for predominantly undergraduate institutions -- has been level funded for the past three years.

We ask the NSF to consider a new program for departmental development of lower-division courses -- one that would include support for instrumentation, development time and supplies for new curriculum, and faculty expansion and enrichment opportunities. Such a new program would emphasize again the integral relationship of each of the parts of the undergraduate academic experience in science and mathematics. Moreover, it would establish a means by which the experiences and resources of predominantly undergraduate institutions can serve as models for strengthening undergraduate science and mathematics.

In all of these programs, one criterion in determining grants should be the impact that an award will have on attracting and sustaining student interest in science and mathematics. A more targeted focus on courses for science literacy for all students should be announced, perhaps supported jointly between the NSF, the National Endowment for the Humanities, and the Fund for the Improvement of Post-Secondary Education. We understand that the NSF, the NEH and FIPSE have just begun such an initiative. We applaud it. The means by which the impact of the proposed projects would be evaluated and by which their activities would be disseminated to the larger community should also be a review criterion.

Parallel to the recommendations of adequate funding levels and expanded programs, we recommend that the NSF establish a budget line item for these programs, and hold a single office accountable for coordinating the distribution of grant funds. We recognize NSF's current rationale for cross-directorate programs; however, funds "targeted" within research directorates for undergraduate programs have often become the first casualty when available funds for research are not adequate. If we are to move with all deliberate speed to achieve the essential reformation in introductory courses at the undergraduate level, there must be within NSF a strong, highly visible office where these programs are initiated, integrated and coordinated. We believe that office should be USEME.

INITIATIVE II. SUPPORTING THE INTEGRATED TEACHER/SCHOLAR ROLE OF UNDERGRADUATE SCIENCE AND MATHEMATICS FACULTY.

*Recommendation #4: The NSF Research Experiences for Undergraduates (REU) program be expanded so that more students from liberal arts institutions can be provided the opportunity to do research at their home institutions and to allow REU Supplements to be used flexibly to support student-faculty research in predominantly undergraduate institutions, especially for those groups underrepresented in science.

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***Recommendation #5:** The NSF programs for undergraduate faculty supporting professional growth, including research and other scholarly activity, be strengthened and broadened.

The hands-on, discovery-based, laboratory-rich approach we advocate requires that teaching faculty be actively engaged in scholarship. Faculty active in scholarship foster a culture that enhances the community of learners; these faculty are often the most productive leaders in curriculum reform and laboratory improvement efforts, locally and nationally. Faculty active in scholarship are the most effective role models for students, and faculty-student research partnerships have been shown over and over to be a critical pump in the career pipeline. The distribution of revised Important Notice #107, which requires researchers to document the "...effect of the proposed research on the infrastructure of science and engineering..." was a welcome step in recognizing that teaching and research should be integrated activities in the nation's colleges and universities.

We strongly support the REU program. However, because of the level of funding, only a small fraction of Site awards presently can be used to support students at their own institutions. This has discouraged significant numbers of highly qualified departments at undergraduate institutions from applying. Just as graduate departments use this program to recruit students to attend their graduate programs, undergraduate departments should be given the resources to use this program to recruit students into science and to retain them in science, mathematics, and engineering. The most successful graduate students are those who have a solid grounding in research techniques -- who know what science is about.

The on-campus research programs of undergraduate faculty are supported through the NSF Research in Undergraduate Institutions (RUI) program. Maintaining and enhancing this valuable program is critical to the overall effort of strengthening the undergraduate academic experience. Given its distributed nature, strong oversight of RUI by a single office must be reinstituted to ensure that the importance and distinctive characteristics of undergraduate research continue to be recognized. We further recommend that the NSF consider a simpler, streamlined award system for small-scale individual grants for undergraduate faculty. In addition, we recommend investigation of a modified program of start-up grants for undergraduate faculty, with criteria similar to those within the current Presidential Young Investigator Program, but at a level of support more appropriate to the needs and scale of research of faculty at predominantly undergraduate institutions.

We recommend further that the NSF establish a faculty development program that would support faculty exchanges between strong undergraduate institutions. In our studies we have found many successful teacher scholars in undergraduate institutions who can serve effectively as mentors and role models for colleagues at other undergraduate institutions. A program of faculty exchanges would provide important opportunities for joint curriculum development based on disciplinary, technological, and pedagogical advances. It would also assist in the development of partnerships working together toward the common goal of strengthening the undergraduate experience in science and mathematics. This award would parallel the current ROA program which enables undergraduate faculty members to do research at major universities.

The Neal Report recommended that the NSF spend $17 million by 1991 for programs focused on the enrichment of undergraduate faculty. The 1992 budget request for the Undergraduate Faculty Enrichment program, though increased over past years, is $6 million. This is inadequate. We take 400 as the base number of science-active undergraduate institutions. If the NSF is to have an impact at such institutions across the country, support for faculty enrichment programs must be expanded.

INITIATIVE III. MAKING DISCIPLINARY CONTENT AND ACTIVE LEARNING CENTRAL TO THE EDUCATION OF K-12 TEACHERS OF SCIENCE AND MATHEMATICS:

*Recommendation #6: NSF priorities for the pre-college sector include encouraging colleges to redirect the structure and content of their teacher preparation programs to focus more directly on science and mathematics -- utilizing an active, investigative, hands-on, content-based approach.

*Recommendation #7: NSF support a wider range of pre- and in-service activities for K-12 teachers, making use of the resources of all colleges with strong undergraduate programs in science and mathematics.

The single most important determinant of what elementary and secondary students learn in science and mathematics is how much their teachers know. Teacher preparation must include substantial, deep exposure to the content of subjects they will eventually teach. Teachers for the nation's K-12 community must be pre-service and in-service involvement with a hands-on, laboratory-rich, active learning experience with science and mathematics. This must be the way they are prepared in their undergraduate courses, another reason why NSF's first undergraduate priority must be reform of introductory courses.

In setting NSF priorities for K-12 programs, we urge you to remember that undergraduate colleges, particularly those in the Carnegie Liberal Arts I classification, graduate higher percentages of their students with majors in science and mathematics. These colleges, whose faculty are committed to the hands-on approach to learning, are natural sources of a substantially increased stream of properly educated science and mathematics teachers. These colleges are also excellent resources for the development of new materials for science and mathematics at the pre-collegiate level.

A large number of the colleges for whom we speak have entered into formal and informal partnerships with schools, bringing teachers to campus as research associates, and providing opportunities for teachers to gain new understanding about disciplinary advances and pedagogical approaches. It is clear from our Project Kaleidoscope research that the potential is great for effective collaboration in faculty/teacher development opportunities and in the design of new materials for the elementary and secondary levels. These cooperative

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opportunities should be expanded, including their incorporation into REU projects, and expanding the ROA program to include K-12 teachers. We see education as a "seamless web," and the undergraduate sector as a key strand in the web.

INITIATIVE IV. DEVELOPING PARTNERSHIPS FOCUSED ON STRENGTHENING UNDERGRADUATE SCIENCE AND MATHEMATICS

***Recommendation #8**: The NSF provide opportunities for regular national and regional colloquia to discuss what works in undergraduate science and mathematics education.

***Recommendation #9**: NSF guidelines outline specific criteria relating to partnerships between schools and colleges, colleges and universities, and colleges and the private sector, focusing on faculty and curriculum development activities, evaluation and dissemination.

***Recommendation #10**: Discussions about the proposed super computer highway include linking undergraduate science and mathematics faculty so that they can communicate regularly about research and teaching interests and have access to regional and national computing centers. Pre-college teachers of science and mathematics also should be linked to this highway.

It is clear that each sector of the science and mathematics education community has a unique contribution to make in addressing national goals; it is equally clear that we can accomplish more by working together than by working separately. The NSF has the ability to develop and sustain such working partnerships on a national basis, and to model within its own structure how such partnerships can be developed and sustained.

The success of many of the current networks supported by the disciplinary organizations, educational associations, private foundations, and corporations, demonstrates that there are significant numbers of persons who are ready and prepared to work together to strengthen the nation's scientific and educational enterprise. Our Project Kaleidoscope research has uncovered a growing national consensus about what works in science and mathematics and a commitment to get on with the task of improving the programs for which we are responsible. We recommend that the model of the Project Kaleidoscope National Colloquium, bringing together institutional teams -- including presidents, deans, faculty members and development officers -- be considered in the planning of further colloquia.

Level of NSF funding is not the only way to identify strong programs. The networks to be developed should include representatives from all segments of the educational community. These networks should have at their center those colleges and universities that have a demonstrated productivity in undergraduate science and mathematics.

As one example, with support from the Kellogg Foundation, there was a large representation at the National Colloquium from the Historically Black Colleges and Universities. Their contribution during the colloquium was significant; equally significant, we hope, are the connections that were made for cooperative efforts in the coming months and years.

A final concern -- of critical importance, though we have not included it as a separate recommended initiative -- relates to facilities. The magnitude of the facilities deficit at predominantly undergraduate institutions is known to us all. If needed reforms are to be made in introductory courses and meaningful research opportunities are to be provided for faculty and undergraduate students, our facilities must accommodate such reforms and programs. It is hard to imagine how predominantly undergraduate institutions across the country are going to tackle successfully the pressing facilities problem without the NSF as a major player. With its peer review process exerting quality control -- eliminating pork barrel decisions about academic priorities -- and with the leverage its support can bring as colleges seek funds for facilities from other sources, a facilities program at NSF is critical. The recent NSF program for facilities modernization (RFO) was a promising beginning; we regret that this program is not included in the current NSF budget request. Of particular value in the RFO program was the formula distribution of funds between educational sectors. This was a clear signal that each sector had much to contribute to the total national effort; this model should be continued as further NSF programs for facilities and for major instrumentation are planned.

We urge the NSF to take a leadership role on the facilities issue, and join with Congress and the nation's colleges and universities to determine how to balance the infrastructure needs of all sectors of the research and research-training communities. The current plan to provide support for major research instrumentation rather than for research and research-training facilities does not address the need for better balance in NSF support to the different sectors of the community. It would be particularly helpful if the NSF would establish a multi-year facilities program linked to course and curriculum development and the acquisition of instructional instrumentation. Colleges and universities could then build such an NSF program into their long-range plans for facilities modernization. A study of the needs of the undergraduate sector for teaching, research, and research-training facilities would assist in developing the necessary long-range plan.

Mr. Chairman and Members of the Subcommittee, those are the Project Kaleidoscope recommendations. They represent a broad consensus of views within the undergraduate liberal arts college sector of higher education. We believe their implementation will move us forward strongly toward improved national performance in science and mathematics. I thank you for the opportunity to make our case to the Subcommittee.

EXHIBIT "A"

Tables: Federal Support

Table 1. FCCSET Committee on Education and Human Resources FY 1992 Budget Matrix *(dollars in millions)*

EDUCATION LEVEL/ MAJOR PROGRAM AREAS	FY 92 BUDGET REQUEST	AGENCY NSF	ED	DOE	DOD	DOI	NASA	DOC	HHS	EPA	USDA
UNDERGRADUATE FORMAL & INFORMAL	100.0%	27.7%	3.1%	6.3%	39.9%	0.4%	3.2%	1.0%	14.7%	0.9%	2.6%
Program Evaluation/Assessment	100.0%	—	—	73.1%	—	—	—	1.0%	25.9%	—	—
FOUR-YEAR, FORMAL TOTAL	100.0%	37.4%	4.8%	—	32.1%	0.5%	2.5%	1.0%	17.8%	0.1%	3.7%
Faculty Preparation/Enhancement	100.0%	99.4%	—	—	—	—	—	0.2%	—	0.4%	—
Curriculum Development, Total	100.0%	87.6%	8.7%	—	—	0.3%	2.4%	0.7%	0.2%	0.1%	0.0%
Curriculum materials	100.0%	81.6%	13.0%	—	—	0.4%	3.5%	1.1%	0.3%	0.1%	0.0%
Laboratory Equipment	100.0%	99.9%	—	—	—	—	—	—	0.1%	—	—
Comprehensive (Org. Reform)	100.0%	31.6%	—	—	17.4%	—	4.3%	1.4%	13.5%	—	31.9%
Student Incentives	100.0%	12.6%	5.1%	—	51.0%	0.8%	2.5%	0.7%	27.3%	0.1%	0.0%
Direct Student Support	100.0%	12.6%	5.1%	—	51.0%	0.8%	2.5%	0.7%	27.3%	0.1%	0.0%
Bridging Programs	----	----	—	—	—	—	—	—	—	—	—
Other	100.0%	48.0%	—	—	—	—	5.7%	35.9%	10.3%	—	0.0%

Taken from FCCSET-EHR Report

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Mr. WOLPE. *Thank you very much. Dr. Light.*

TESTIMONY OF DR. TIMOTHY LIGHT, PRESIDENT, MIDDLEBURY COLLEGE, MIDDLEBURY, VT

Dr. LIGHT. Mr. Chairman, I am grateful for the privilege of being here. This is something I have waited for for a long time, and it is a great opportunity. I am not a scientist, like the members of the committee, and therefore I cannot speak technically, and I would not be able to answer any technical questions. However, ironically over the past five years, I have had major responsibility for two science colleges, and in those institutions I have learned three things.

First, we have a national crisis in the production of future scientists. We are in effect eating our seed corn. Secondly, as a Nation, our Federal policy is doing next to nothing to solve that problem. Thirdly, the small, private sector, which we are dependent upon to solve that problem, is increasingly unable to meet the costs of serving its traditional role in disproportionate production of scientists for the future.

I refer to a science college. I was provost and an acting president at Kalamazoo College in Michigan, and am now president of Middlebury College in Vermont. These two colleges, along with some 50 others, are known as the science colleges. They are known as that because they produce disproportionate numbers of graduates in sciences who then go on and get Ph.D.s and become professional scientists.

What makes a science college? I think probably two things. First of all, they teach science through an apprenticeship method of teaching, and the students become scientists while they are undergraduates because they are doing research collaboratively with their instructors. The faculty are hired to be teachers and researchers, not researchers separated from their students.

Secondly, the students come from traditional middle and lower income families with a very strong work ethic who attain great pleasure by hard work devoted towards something which is of service to their country.

I would like to leave you with three facts which I hope will be of importance in the future. First, this Nation has been and still is very dependent upon the small private sector for the production of scientists. It is much more dependent upon the small private sector than anything in national policy or national funding would suggest.

Secondly, the costs of doing undergraduate science have escalated in proportion to everything else we do at a point where thirdly, we cannot continue to keep up the quality at the level which we historically have done.

What is needed? The problem with stating what is needed is that the sums which we need are important to us, but are so insignificant in terms of the overall Federal budget that they get lost in Washington. First, we need an infusion of money for science facilities—buildings and laboratories—at approximately $100 million per year, which we could compete for and for which we would be able to raise matching funds.

We need faculty research support. We need student research support so that student jobs would be related to their work in science. We need equipment support because the renewable equipment in science is one of the costs which we are increasingly unable to meet. And finally, we need support for course and curriculum development.

In closing, I would like to tell you a little story. I indicated I am not a scientist, my field is Chinese linguistics. I am more familiar in Washington in dealing with the International Division of the Department of Education than I am with the science areas.

Federal funding in both foreign language and international studies on the one hand and science on the other got started as a result of the Sputnik scare, and were part of the original same legislation. By about 1980, those in charge of the International Division of the Department of Education had realized the funding that had gone into this was not producing people who spoke foreign languages in the way they had imagined.

Starting in 1980, they tied future funding to a demonstrated ability to handle undergraduate instruction. This kind of care and concern from the bureaucrats in Washington, from those who are in charge of our programs, is something which has had a tremendously positive effect across the country.

As a neophyte in science but as one who has had responsibility for two of the Nation's science colleges, I have not found the same kind of targeted interest in undergraduate education making the same kind of difference. That and the levels of funding for the specific projects I have named, to me are the things which are going to make the difference between now and the end of the decade when the crisis will hit if we don't attend to it now.

Thank you very much.

[The prepared statement of Dr. Light follows:]

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Office of the President

TESTIMONY ON SCIENCE

BEFORE THE INVESTIGATIONS SUB-COMMITTEE
OF THE
COMMITTEE ON SPACE, SCIENCE, AND TECHNOLOGY
OF THE
UNITED STATES HOUSE OF REPRESENTATIVES

July 11, 1991

BY

DR. TIMOTHY LIGHT, PRESIDENT, MIDDLEBURY COLLEGE

Mr. Chairman:

I am immensely grateful for the opportunity to speak to this Committee. On behalf of Middlebury College and colleagues all over the country, I wish to express gratitude to you for your interest and concern for the teaching of undergraduate science in the United States. I've waited a long time for the opportunity to present the undergraduate case to members of Congress in this fashion, and I am more thankful than you may imagine that this has today come about.

Like you who are members of the Committee, I am not a scientist. I cannot speak technically. I cannot answer technical questions. There are others here who will be able to do both of those things. I cannot even discuss with any measure of certitide the various categories of funding and program which are used by the National Science Foundation (NSF). Again, there are many testifying before you today who will be able to deal with those matters in accurate detail.

However, although not a scientist, for the past five years, I have had a major responsibility in two of the United States' principal science colleges. From that experience, I've learned that we have a crisis in this country in the production of future scientists. We are not producing enough scientists to meet our future needs now, and as we look down from the graduate schools through colleges into the high school and elementary school grades, we can predict already that there will be a substantial dearth of new scientists when the decade and the century change.

From my experience in these two science colleges I have also learned that as a nation--I mean specifically federally--we are doing little of significance to meet that crisis. Most importantly from that experience in two science colleges, I have learned that, while the nation is inordinately dependent upon the small private colleges for the production of excellent scientists, without federal funding assistance, the small private college simply cannot continue the unparalleled work which has been one of their marks of greatness throughout this century. For, even though the country has depended upon the small private liberal arts college for the source of a great many of those who go on and take PhDs in science and become career scientists, and even though these private institutions have devotedly and cheerfully been the nation's most reliable source of supply of future scientists throughout this century, the costs of doing science at the undergraduate level have risen so fast in the last few decades that these schools simply cannot keep up at the level which they have previously been able to manage.

I have referred to science colleges and mentioned two in particular. For three years I was Provost at Kalamazoo College in Kalamazoo Michigan and for a year the Acting President of that institution. I am now President of Middlebury College. Both of these institutions are part of a group of fifty small, private, independent institutions which are known as the "science colleges". These institutions are responsible for a disproportionate number of graduates in science and correspondingly a disproportionate number of graduates who then go on to take PhDs in the sciences and become professional scientists in their careers.

The question is frequently asked why is it that these schools are particularly successful at the production of scientists. I would suggest that there are two reasons:

First, these institutions are able to offer an apprenticeship model of education. From the very beginning, the future scientist is only given a true student-mentor relationship with teachers. In contrast to those institutions where classes are so large that students' contact with their teachers occurs mainly in large lecture halls and in laboratory classes where the results are predetermined and canned, in these science schools, youngsters are brought in to collaborative research with their faculty. I understand from scientific colleagues that one of the important keys to this process is that students learn early how to fail in testing their hypotheses. It is the failure of what appeared to be a good hypothesis that turns one into a scientist, I am told. It is only the intense attention that youngsters are given in these small schools which permits that process to occur. The faculty in the science colleges are hired because of their devotion to teaching. While the faculty do indeed do research, the research which they undertake is directly related to their teaching function, and they undertake research projects which most often engage their students as well as themselves. At the science colleges it is not the norm for faculty to undertake research which takes them away from their teaching obligation and becomes a substitute for teaching.

The second principal reason why the science colleges have been so successful has to do with the traditional student populations that attend these schools. Traditionally, the small liberal arts colleges have been attended by youngsters from the middle and lower economic classes, youngsters from families with a very strong work ethic, youngsters for whom the challenge of an intriguing and difficult subject and untold hours of hard work is looked at with great pleasure, youngsters who can foresee a career which is challenging and demanding and stimulating and which provides service to society.

* * * * *

There are three facts which I would like to leave you carrying with you, if I may.

1. Throughout this century the United States has been more dependent upon the small private sector of higher education for the production of future scientists than is widely understood. That dependence continues

today. It is a much greater dependence than anything in national science policy, and particulary in anything in national science funding, would lead one to believe.

2. Undergraduate science costs are escalating at a rate much faster than the costs of the other academic programs which small liberal arts colleges must mount with equal excellence. To be sure, as is widely known, the costs of providing all of our programs have risen for our colleges in excess of inflation for the past decade and more. Some of those excessive cost rises are the result of federal programs and federal regulations. Some of the cost increases are the result of demands by society for new programs and facilities in colleges. The dramatic rise in the cost of doing science is, however, the result of the increased sophistication that is characeristic of science and the availability of excellent equipment for teaching and teaching-based research.

3. The small private colleges in general cannot keep up with the rising costs of equipping their labs, renewing and rehabilitating labs, providing research support for students and faculty, without dipping into the funds needed for other programs of equal importance for liberal arts.

In short, we have a nation that is dependent upon this sector, the costs are rising too high too rapidly, and this sector in general will not be able to make it through the whole of the coming decade without some help in maintaining the very high standards that have been maintained in the production of scientists throughout this century. Certainly, the wealthiest schools will be able to continue, but many of the most productive science schools are not wealthy, and at those schools something is going to have to give.

* * * * *

Turning now to what is needed, the principal problem that the small private colleges face in attempting to obtain government attention is that the funds which are needed, while very large and important for us, are so small as to get lost in Washington. The small, private liberal arts college is extraordinarily cost efficient. It has had to become so because, from the very beginning of most of the liberal arts colleges, there has never been enough money. A shoestring and bootstrap culture has developed in these institutions. There is a habit of doing more with less and a constant reliance upon figuring out ways to add to the tasks that are to be undertaken without drawing more upon the limited resources that are available.

I would suggest that there are five categories of need. As I have indicated above, not being a scientist and not being directly involved in NSF, I can speak only to the needs as they appear on a college campus and as they appear in realistic terms to the eye of the average person.

1. Facilities. The most expensive and crushing problem is the cost of providing new facilities where those are needed and of renewing and rehabilitating old science buildings where that is called for. Knowledgeable sources have estimated the deficit in undergraduate science facilities in the United States to be well over a billion-dollar problem. The litany of deficits which are faced by the science colleges with their outdated and often only partially working facilities is legion. It will probably suffice to point out simply one among the many frequent problems which are faced in the science colleges when looking at science buildings in current use. Even among buildings that were built as recently as twenty or twenty-five years ago, there is a tremendous problem of exhausting noxious fumes. The problem is at least two-fold. On the one hand, the technology for eliminating noxious fumes has developed considerably over the past couple of decades so that much better facilities are available for those schools that can afford them than was the case twenty years ago or so. On the other hand, we know a great deal more about environmental damage to the human body, and many of the fumes and chemicals which were considered to be acceptable for human breathing some time ago are now known to be dangerous. For that reason, our standards have risen considerably, and our sense of risk in science buildings which are not brand new has correspondingly gone up. In short, we have far too many science buildings being used daily by undergraduates which either do not work for today's science or which are plain dangerous.

2. Faculty Research Support. As I have indicated above, research in an undergraduate college is considered vitally important, but is student-oriented.

We consider research important for faculty because it is very important that they keep their intellectual activity always moving forward and keep up to date with their discipline, and that they engage in the renewing effect which only participation in the field can permit. As I've indicated above, however, research in a teaching institution is intended to be directly or indirectly related to the teaching function, and faculty draw undergraduate students into their research as early as possible in the career of those students. The research support that is being sought is not for research which is designed to take faculty away from the classroom and keep them isolated from their students. On the contrary, the research support sought is support for faculty research projects which will involve students and which will inform the teaching of those faculty members.

3. Student Support. For undergraduate students to be able to participate with their mentors in research, it is important that there be a source of funding which will allow them to work in laboratories rather than selling hamburgers or newspapers. Not that selling hamburgers and newspapers is not salutary for one's moral development. However, becoming a scientist is an arduous and time consuming and long-term task. One of the things that the undergraduate institution provides is an environment where it is possible for the youngster to become a scientist at a very early age because his or her mentors are there together with their students at all times and because the teachers engage in collaborative research with undergraduate students. National policy has put stipends very largely in the hands of graduate students. Certainly graduate students must have that kind of support or we will not have a science cadre. But the same argument must apply to the undergraduates at the science colleges as well.

4. Equipment. Renewable equipment turns out to be one of the most expensive things in the academic budget for the small college. It is uncertain that the provision of equipment needed for young faculty starting off their research right after completing the PhD, for student collaborative research, and simply for keeping up with our laboratories is something that we can afford from year to year. The NSF has a remarkable program called ILI. The ILI program permits the awarding of funding for equipment for undergraduate institutions on a one-for-one matching basis. This is not an ungenerous

program. However, the costs of higher education are such and our inability to continue to raise our access to resources proportionately that more than one school has recently breathed a sigh of relief when not all of its faculty's applications for the ILI program have been funded. There are years when it simply isn't possible to find the matching money for ILI awards.

5. Course and Curriculum Development. A great deal of innovation is being brought into American science from teaching in the small liberal arts colleges. Heavy teaching loads, continuous research demands, and lots and lots and lots of time spent out of class with students in laboratories all mean that there isn't sufficient time or resource for faculty to develop all of the creative teaching ideas which they have. For this reason, curriculum support turns out to be pretty vital.

* * * * *

To sum all this up, from one lay person to other lay persons, we have a national crisis. We have a sector of higher education which has traditionally been a major source to solve that crisis. That sector, the small private liberal arts college, is facing cost increases to the degree which will make the continuous support of undergradute science at the level of quality and quantity which has historically been its mark increasingly difficult to meet. The sums which will be needed by the liberal arts colleges across the nation are miniscule compared to other things that the government takes up, and even miniscule compared to other things which the National Science Foundation takes up. For this reason, it is often not evident how much these colleges are in need of that level of support right now for the science programs.

The categories of funding in which support is most needed are those categories which relate directly to the teaching mission of the liberal arts college and thus to the production of future scientists. They are: facilities, faculty research support, student research support, equipment and course and curriculum design.

* * * * *

It has indeed been a great privilege to be able to speak before this Committee. It is an immense source of citizenship pride that a group of Congressman would be taking such a deep interest in a national problem of this magnitude and this importance. Thank you very much.

Mr. Wolpe. Thank you very much, Dr. Light. I should take this opportunity to express my personal appreciation to you for focusing me on this issue before I came into the chairmanship of this subcommittee. At that point I was off on my other life of African affairs. It was really your advocacy of a couple of years ago that moved us to focus some attention on this problem and I am grateful for that assistance.

Dr. Light. Thank you. I'm grateful, too.

Mr. Wolpe. I would like now to turn to Dr. Doyle.

TESTIMONY OF DR. MICHAEL P. DOYLE, D.R. SEMMES DISTINGUISHED PROFESSOR OF CHEMISTRY, TRINITY UNIVERSITY, SAN ANTONIO, TX

Dr. Doyle. Mr. Chairman, I am here today to speak to you from the trenches as an educator about the pending shortages of scientists who are educated in the United States, and specifically about programs already underway at the National Science Foundation that were designed to relieve these shortages.

The number of students who are choosing science for their careers is declining at a rate that is much steeper than that predicted by demographic data. Already shortages exist at the bachelor's level, in the scientific work force, and the declining pool of bachelor's level scientists signals similar future shortages of advanced degree scientists.

Historically and continuing today, the greater percentage of students whose education is obtained primarily at undergraduate institutions choose science careers. This success stems not from institutional size or facilities; instead, the scientific interests of these students are nurtured best at undergraduate institutions in what has become a new American revolution in education.

Young and inexperienced students are guided to their future in science through participation in undergraduate research. This experience, obtained without the usual academic formalities, fuels the fire of discovery in a great majority of the fortunate few who are provided with this opportunity.

The National Science Foundation has recognized the importance of undergraduate research as an effective way to develop science careers since its introduction in the early 1960s of its Undergraduate Research Participation program. After a brief period in the early 1980s when such programs were terminated, the National Science Foundation expanded upon its original mandate to maintain the infrastructure of science, and initiated its Research in Undergraduate Institutions program as well as its Research Experiences for Undergraduates program in 1984 and 1985, respectively.

Both of these programs provide the means to involve undergraduate students in research, and thereby stimulate their interest for careers in science. They have in fact created research active environments for undergraduate students to prepare them—and here I quote from an address given by the Honorable George Brown, Jr., to Project Kaleidoscope: "To be able to respond creatively to unpredictable change." No other experience in undergraduate education provides students with such a beginning, such a preparation.

During the past year, however, signs of strain in the implementation of these programs have appeared. Budget allocations for both RUI and REU programs have declined, and the number of proposals submitted to them is not increasing. The RUI program is invisible to a significant constituency of undergraduate institutions and standards for proposal review vary.

The REU program is diffused in its implementation, focused on drawing students away from their home campuses, where one is most effective in engendering their careers in science, and sometimes unjustifiably narrow in its focus.

These programs are in need of review and changes that would make them more suitable for the growing need to engender desirability for science careers among these undergraduate students. In these reviews, one would hope that the valued programs could be strengthened, and greater benefits realized.

Significant attention is placed at the precollege and post-baccalaureate levels to address the serious developing shortages in the work force of our science and technology. However, too little attention is given at the college level, where in fact the vast majority of career decisions are finalized.

There is a need to coordinate research programs at all Federal agencies that are designed to enhance undergraduate career development in the sciences, and I recommend this consideration be given to providing the National Science Foundation, which has had experience in this endeavor, with this authority.

I noted last evening, in receiving the report of the FCCSET committee on education and human resources, that the topics of research in undergraduate institutions and for undergraduates is lacking in focus for the undergraduate experience.

I have been associated with undergraduate institutions during my entire professional life. My efforts have been directed to ensuring that students in my charge reach their full potential. The opportunity to be engaged in research, even during their freshman year, has been my gift to them, and they have responded with excitement and enthusiasm that is contagious.

I, and a significant number of the most effective educators in this country, would lose their effectiveness without the opportunity to perform research with undergraduate students. For us, research is the ultimate educational experience, and has never been a substitute for teaching. Thank you for this opportunity to be with you this morning.

[The prepared statement of Dr. Doyle follows:]

TESTIMONY

Michael P. Doyle
D.R. Semmes Distinguished Professor of Chemistry
Trinity University
San Antonio, Texas

"Traditional and Nontraditional Sources of Future Research Scientists"

July 11, 1991

UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

INTRODUCTION

Thank you for the opportunity to appear today before the House Subcommittee on Investigations and Oversight to present testimony on undergraduate science education. The importance of this hearing on "Traditional and Nontraditional Sources of Future Research Scientists" cannot be overestimated. An unprecedented decline in the selection by undergraduate students to major in the sciences began more than a decade ago and shows no sign of abating. In the discipline of chemistry, in which I was educated and practice with enthusiasm, there has been a 27% decrease in the number of chemistry graduates since 1981, and the vast majority of this decline has occurred during the past 5 years (Exhibit 1). Similar changes have occurred or are occurring in the biological sciences, geological sciences, physics and astronomy, and the mathematical and computer sciences. In the chemical sciences, which accounts for half of the total workforce involved in research and development in the United States, the loss of as much as 27% of the total number of potential future employee signals a severe stain on the infrastructure of its dependent technologies.

Undergraduate students are often treated as a wholesale commodity - not as important as the raw material from which they are drawn and not as visible as the retail product. They are intermediates, considered too old to be influenced to enter science and too inexperienced to be productive in science, and they are left with little support or consideration in national science policy. Yet this is the educational level at which the highest percentage of students with initial interest in the natural sciences and engineering is being lost to these careers. *If only one third of the 160,000 students who leave science and engineering in colleges and universities could be retained, the pool of available scientific talent would increase by 20%, and shortages in the scientific workforce, currently and in the future, would be minimized.*

My comments today are drawn from a 23-year teaching career in liberal arts colleges, a dedication to education through investigative research, and an extensive array of experiences in the setvice of fostering education and research. I received my undergraduate degree from the College of St. Thomas in Minnesota and, after obtaining my Ph.D. degree from Iowa State University, I returned to the liberal arts setting - first at Hope College in Michigan and now at Trinity University in Texas. Since the first weeks of my employment as a faculty member, I have continued to work directly with undergraduate students in investigative research. More than 200 students have passed through my supervisory hands in this endeavor, and more than half of them have become professionals in science - as faculty in universities and as research scientists and managers in industry or government - most after receiving advanced degrees. I speak with you today from these experiences and with the concerns of the future generation of scientists.

I also come to you with experience as a former member of the Advisory Committee for the National Science Foundation's Division of Chemistry, where I participated in the design of two programs - *Research in Undergraduate Institutions* (RUI) and *Research Experiences for Undergraduates* (REU) - that have successfully impacted the career development of undergraduate students in science. As a founding member and past-president of the Council on Undergraduate Research, a society for the advancement of scientific research at primarily undergraduate colleges and universities (Exhibit 2), I bring you results from a recent survey on undergraduate faculty need for and satisfaction with the NSF-RUI program. I will also speak to you as a member of the Advisory Committee for "Project Kaleidoscope" which has recently completed an extensive study on the investigative environment of liberal arts colleges and has reported a comprehensive plan for strengthening undergraduate science and mathematics.

Today in this Oversight Hearing on "Traditional and Nontraditional Sources of Future Research Scientists" I will direct my comments to

(1) The importance of existing Federal programs, especially those at the National Science Foundation, for undergraduate student career development in the sciences; and

(2) The necessity of oversight and coordination.

These comments will include recommendations for changes in Federal programs, especially those at the NSF, that would benefit undergraduate science education. They are colored by my strong belief, reflected in several Federal programs, that undergraduate research, an American invention, is the most exciting educational development of the second half of the 20th century. Its origin and integration into undergraduate science education are outlined in Appendix A, to which I would draw your attention as suitable background for the comments that I am making. The focus of my comments, therefore, is on programs that support the people that make science exciting and enjoyable. More than bricks and mortar, more than classroom teaching, the personal interaction between students and their mentors is what has made science an attractive venture for this nation's young and a productive enterprise for the United States.

THE IMPORTANCE OF EXISTING FEDERAL PROGRAMS FOR UNDERGRADUATE STUDENT CAREER DEVELOPMENT IN THE SCIENCES

Undergraduate research experience is the single most important factor in the decision of most students, especially those whose baccalaureate origins are from predominantly undergraduate institutions, to enter graduate school in the sciences, and the quality of their experience contributes to their overall success. For 224 private and public undergraduate institutions whose total combined enrollment is 1.03 M students and in which research in the chemical sciences is an expectation of both faculty and students, their contribution to the scientific pool demonstrates the importance of undergraduate research (*1*). For the period 1985-1988 these institutions graduated 11,302 chemistry majors, 31% of the total from U.S. colleges and universities, and 3178 of them entered gradate school in chemistry or biochemistry, more than 35% of entering graduate students who are U.S. citizens. Similar data exists for the biological sciences (*2*) and physics and astronomy (*3*) at predominantly undergraduate institutions. In addition, these same institutions do not show the same decrease in student career development in the chemical sciences that exists nationally (Exhibit 3). Complimentary data has been provided by "Project Kaleidoscope" (*4*) with the same conclusion.

The principal cause for this maintenance of student interest in the sciences at predominantly undergraduate institutions has been the increase in undergraduate research participation (Exhibit 3), and the major contributor to the growth in the availability of these opportunities has been Federal programs introduced since 1983, especially:

- Research in Undergraduate Institutions (RUI) Program (1984) - National Science Foundation
- Research Experiences for Undergraduates (REU) Program (1985) - National Science Foundation
- Academic Research Enhancement Award (AREA) Program (1985) - National Institutes of Health

Of these three, the RUI program has had the strongest and most sustained impact on undergraduate student career development in the sciences at predominantly undergraduate institutions. This program, funded through the NSF Research Directorates, supports scientific research by individual investigators in academic departments that do not have the Ph.D. program. Proposals are judged by their scientific merit with the understanding that, because of the time demands on faculty where teaching undergraduate students is their primary function, productivity may be lower than that found from faculty in graduate departments at research institutions. Grants awarded support research that involves undergraduate students.

When first proposed by the Council on Undergraduate Research to the National Science Board (1983) to be reviewed and funded through the NSF Research Directorates as a merit-based program, the budget estimated for significant impact by what became the RUI program was $3 M. Enacted by the National Science Foundation for implementation in 1984 as a "targeted" program without a separate budget, grant awards in this fiscal year totaled $6.65 M - over twice that of the initial target. During FY 1984 a total of 141 grants were made under the RUI program, and 75 of these were made to faculty from predominantly undergraduate institutions who had never before been principal investigators for any NSF grant (*5*). Since that first year, the NSF target for this program has grown to $16 M in FY 1988, $20 M in FY 1990, but decreased to an anticipated $14.5 M in FY 1991 and is proposed to be only $18.725 M in the FY 1992 budget. Although a portion of the anticipated decrease in allocation for the RUI program in FY 1991 is due to a decline in proposal pressure from predominantly undergraduate institutions, there is reason to believe this opportunity has become invisible to many faculty, especially those just beginning their academic career, and that an oversight review of this program is warranted.

A survey of 1200 members of the Council on Undergraduate Research, from which 692 responses (58%) were returned, disclosed that the NSF-RUI program is responding responsibly to the pressure it is receiving (Exhibit 4). Of importance in assessing the impact of this program, although only 35% submitted a proposal to the NSF-RUI program, nearly half of all respondents stated that the NSF-RUI program "encouraged research-active faculty to expand their research in scope or productivity", "promoted the involvement of students in research", and "encouraged students to pursue research careers". Still, this survey suggests that evolution of the RUI program to better meet the needs of faculty and students at predominantly undergraduate institutions is warranted.

I propose consideration that the Research in Undergraduate Institutions (RUI) Program undergo comprehensive internal and external review to determine its effectiveness in establishing research-active environments at predominantly undergraduate institutions that enhance student career development in the sciences. An internal analysis of "Research Proposal and Award Activities by Predominantly Undergraduate Institutions" for FY 1988 was reported in March, 1990 (*6*) and represents a valuable beginning. The last and only external review of this program occurred in December, 1984 (*5*), and there are several areas of concern regarding current implementation and impact of the RUI program that are in need of study. The outcome of the recommended review can be expected to provide an informed projection for future budget allocations and the strengthening of the RUI program to better meet the needs of undergraduate faculty in establishing research-active environments. This recommendation is consistent with that made by "Project Kaleidoscope" for the RUI program (*4*).

Instrumentation for the conduct of scientific research is essential to research-active environments in predominantly undergraduate institutions, just as it is in research universities. The cost of this instrumentation places a considerable stain on the resources of these institutions, especially small liberal arts colleges, and, increasingly, proposals requesting funding for instrumentation are being subjected to internal restrictions that limit their flow to the NSF for funding consideration. The issue is matching costs expected from the undergraduate institution, and these restrictions are impacting faculty retention and the further development of research-active environments. **I propose consideration that funding for the Research in Undergraduate Institutions (RUI) Program be supplemented to allow cost sharing for major instrument acquisition at 33% rather than at 50%, where applicable in NSF Research Divisions.**

Unlike the RUI program, which is modeled after the "regular" individual investigator program at the National Science Foundation, the Research Experiences for Undergraduates (REU) program is derivative of the earlier URP program that was terminated in 1981, but with some significant differences. A majority of the students who take part in this summer research program come to the site from another institution, and most of them are drawn from academic institutions where there is little or no research activity. The REU program has as a principal objective to attract those students, women and minorities, who are underrepresented in the sciences to undertake careers in the sciences. *No other NSF program is so directly linked in intent to undergraduate career development in the sciences, and no other one is so diffuse in its implementation.*

Each research division at the NSF has its own plan for implementation of the REU program, some favoring sites that maintain 8 or more students and others that fund individual investigators to support 1 or 2 students, some as a 3-year continuing program and others only for one year. In all cases the quality of the research for undergraduates is a factor in review, and this is appropriate, but in many instances ancillary conditions, such as a focus on specific subdisciplines, are enforced, and they limit the participation of predominantly undergraduate institutions in this program. The REU program is perceived by many undergraduate institutions to be designed to support graduate student recruitment by research universities, rightly or wrongly, and the overall impact on and importance to

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undergraduate colleges and universities has been limited.

The NSF budget allocation for the REU program, operated out of the NSF Research Directorates, increased substantially since its introduction in 1985 - to $20.3 M in FY 1990. In FY 1991 its budget is projected to be $14.8 M, a decrease of more than 25% from FY 1990, but the FY 1992 NSF budget request places this program at $19.5 M. There is evidence that proposal pressure to this program has been declining in some of the research divisions and that some initial expectations for this program are not being met. The time has come for a reassessment of this program and for its redesign to meet the primary objective of enhancing student career development in the sciences.

I propose consideration that the Research Experiences for Undergraduate Students (REU) Program be evaluated to address the great divergence in its implementation at the National Science Foundation, to review the restrictions in this program that inhibit students on their home campus from receiving REU support, and to determine the appropriate budget level that would allow this program to be expanded so that more students have the opportunity to become engaged in research at their home institutions. As stated in the report from "Project Kaleidoscope", undergraduate institutions are inhibited from applying to this program (*4*), although they are often more suitable sites for enhancing undergraduate student career development in the sciences than are their graduate institution counterparts. Just as graduate departments often use this program to recruit students to attend their graduate programs, qualified undergraduate departments should be given the resources to use this program to recruit students into science and to retain them in science. Under current REU practice, students from major universities also lack opportunities to become engaged in undergraduate research, so this request should not be interpreted as parochial.

An initiative modeled after the REU program but applicable to high school teachers of science is worthy of consideration. Such an initiative would serve to maintain them as science professionals, link them to colleges and universities, and provide them with an intimate knowledge of the excitement and challenges of modern science. Highly successful programs are currently operative through several private organizations and foundations, but they reach only a small number of qualified teachers. The National Science Foundation, through its EHR Directorate, should be encouraged to consider such an initiative.

The NIH-AREA program, like the NSF-RUI program funds the research activities of principal investigators. Unlike the RUI program, however, the NIH-AREA program was not created with concern for student development in science or for the support of undergraduate students. Less than 50% of the $10 M outlay for this program supports research in science departments that do not have a Ph.D. program. Still, the AREA program does impact many, mainly biology and chemistry, departments at predominantly undergraduate institutions, and funding from AREA grants does support a significant amount of undergraduate research.

Other Federal programs, including the Instructional Laboratory Improvement (ILI) program at the NSF, support undergraduate research indirectly or directly. However, their breadth and direct impact are not comparable to those operated through the NSF Research Directorates.

THE NECESSITY OF OVERSIGHT AND COORDINATION

Undergraduate student research is supported by the NSF (RUI, REU), NIH, DOE, and other Federal agencies. In each program and at each agency there is a different approach, and different outcomes are expected. For example, in attracting underrepresented minority students into the sciences, both the NSF-REU and NIH-MBRS/MARC (Minority Biomedical Research Support/ Minority Access to Research Careers) programs are major contributors, but these programs are often competitors for the same students. Since the NIH programs offer minority students research opportunities at their home institutions and often provide salaries/stipends greater than those offered through the NSF-REU program, a student receiving offers from both programs most often selects the NIH site. The NIH programs attract capable students into the biomedical sciences, and most of them go on to medical school and other health-related careers. The NSF-REU program is designed to promote graduate school opportunities leading to M.S. and Ph.D. degrees and is less competitive for the same students because of a variety of socio-economic reasons.

In the DOE, research opportunities for undergraduate students and their faculty have existed for a long time at the National Laboratories. The model here is collaboration with research scientists on projects that have a high national priority. However, since there is no formal carry-over, other than experience, from the National Laboratories back to the home institution the impact of these opportunities on undergraduate research in predominantly undergraduate colleges and universities is indirect. If these opportunities are to have a more direct impact on the career development on students in science, then a formal mechanism for funding collaborative projects at undergraduate institutions should be developed.

Even at the NSF two programs that have the same objective can operate in competition. An example of this is the acquisition of instrumentation for teaching and research. At predominantly undergraduate institutions where research is a teaching function, it is virtually impossible to separate the two. Yet in many of the research divisions of the National Science Foundation, programs to fund shared research instrumentation are integrally associated with the research support operations, whereas the Undergraduate Science, Engineering, and Mathematics Education (USEME) Division of the EHR Directorate operates the Instructional Laboratory Improvement (ILI) program whose primary focus is instruction rather than research. Both programs fund the same kind and quality of major instrumentation for predominantly undergraduate institutions, but because instrumentation programs in the research divisions are for shared equipment, often departmental, and the ILI program has no such limitation, undergraduate faculty favor the ILI program even though its proposal success rate is lower. The result is an increase in proposal pressure for ILI with complaints of inadequate funding and a decrease in proposal pressure for RUI instrumentation programs with complimentary complaints of inadequate interest.

If undergraduate career development in the sciences is to be a focus of Federal programs, attention must be given to a diversity of approaches, to competition between different programs, and to program requirements that facilitate undergraduate career development. No other Federal agency has the background, interests, or capabilities of the NSF to coordinate these programs, and I **recommend that the National Science Foundation be given the responsibility to coordinate Federal programs designed to enhance undergraduate career development in the sciences.**

CONCLUSION

The invitation to appear before before this Subcommittee asked for my views on the integration of research into undergraduate science education, on the contribution of Federal programs, especially those at the NSF, to undergraduate science education efforts at liberal arts colleges and universities, and for recommendations for changes in Federal programs, especially those at the NSF, that would benefit undergraduate science education.

It would be easy for me to tell you that the budget for existing programs should be doubled and that a variety of new programs should be initiated so that every small college and all science faculty could receive Federal support for their valued educational programs. I have chosen instead to focus on the primary catalyst for student career development in the sciences - undergraduate research - and to inform you that suitable programs exist at the National Science Foundation for this undertaking. They are based on excellence and potential productivity, and they have created research-active environments in predominantly undergraduate institutions. However, they are also in need of course adjustments in order to avoid being lost to the communities that they were designed to serve. Existing programs such as RUI and REU are in danger of losing their competitive attraction to significant components of the academic community. As proposal pressure declines, program budgets are reduced, and a downward spiral in program effectiveness results. Recommendations made in this Testimony would serve to prevent this loss.

The need for oversight and coordination in programs designed to impact student career development in the sciences is becoming increasingly evident as new Federal programs are introduced that impact undergraduate education and research. The National Science Foundation is uniquely composed to play a leading role in such activities.

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Professor Michael P. Doyle, Trinity University
July 11, 1991

EXHIBIT 1

Chemistry Graduates from American Chemical Society Approved Bachelors Degree Programs at U.S. Colleges and Universities*

Year	Number of Institutions	Number of Graduates	Number of Graduates Number of Institutions
1990	599	7,650	12.8
1989	593	8,125	13.7
1988	584	8,372	14.3
1987	582	8,848	15.2
1986	580	9,295	16.0
1985	579	9,679	16.7
1984	577	9,819	17.0
1983	570	10,043	17.6
1982	561	9,866	17.6
1981	558	10,453	18.7
1980	554	10,170	18.4
1979	551	10,451	19.0
1978	547	10,350	18.9
1977	534	10,207	18.8

*Data from the American Chemical Society Committee on Professional Training, 1155 Sixteenth Street, N.W., Washington, D.C. 20036.

EXHIBIT 2

COUNCIL ON UNDERGRADUATE RESEARCH

A SOCIETY FOR THE ADVANCEMENT OF SCIENTIFIC RESEARCH AT PRIMARILY UNDERGRADUATE COLLEGES AND UNIVERSITIES

Goals

The purposes of this Society are to provide students at predominantly undergraduate colleges and universities with increased opportunities to learn science by doing it and to provide their science faculty with increased opportunities to continue to develop their own understanding of science by remaining active in research. CUR believes that a discovery-oriented approach to learning should permeate science education throughout the undergraduate science curriculum. Increased opportunities for students to do research as undergraduates effectively draw more students to careers in science teaching and research, and continuing involvement in research assists faculty to become more exciting and stimulating classroom teachers.

The diversity and comprehensiveness of the American system of higher education are unparalleled by any society in any era. At one end of the spectrum are the great research universities, where faculty research is so important that it sometimes overshadows undergraduate teaching, but where faculty expertise, facilities, and equipment are readily available to support research by interested undergraduates. At the other end of the spectrum are institutions where limited resources preclude research by students or faculty. The majority of American institutions of higher education lie between these two extremes. With encouragement, with sharing of successful models, with modest local resources, and with help obtaining external support, faculty at these middle range institutions can develop programs that introduce students to the excitement and challenge of science by doing research as undergraduates.

Accomplishments

- CUR publishes directories which document the very significant role of undergraduate departments and their faculty in the mainstream of science. As a result, funding agencies use the directories in the evaluation of proposals and selection of reviewers. Graduate schools use the the directories in their recruitment efforts, companies use them in the search for talented graduates, and they are even used by some high school students in selecting colleges. Currently, there are directories in biology (Second Edition, 1989, 618 pages, 89 institutions), chemistry (Fourth Edition, 1990, 747 pages, 226 institutions), geology (First Edition, 1989, 682 pages, 133 institutions), and physics/ astronomy (Second Edition, 1989, 537 pages, 124 institutions). The first directory for mathematical sciences, which established a Council in 1989, is in preparation. Initial support for the chemistry directory was provided through a grant from the Petroleum Research Fund of the American Chemical Society, and a grant from the Keck Foundation supported the geology directory.

- CUR publishes a Newsletter in four 100-page issues annually to provide members of CUR and non-member subscribers with successful models for research programs and for their support through acquisition of outside funding. The experiences of CUR members and others in designing and implementing programs in response to special foundation initiatives are disseminated. The

Newsletter pays special attention to sources of funding, including the names and telephone numbers of persons to contact for information. Now in its eleventh year, the Newsletter is distributed to more than 1350 individuals.

- Biannually, CUR sponsors a national conference to examine critical issues affecting science education at primarily undergraduate institutions. The third such conference brought nearly 300 science faculty, college administrators and representatives of federal agencies and private foundations to Trinity University in San Antonio in June, 1990, to examine "The Role of Undergraduate Research in Science Education: Building and Funding a Successful Program". Networking among college scientists involved in other cooperative efforts to enhance undergraduate science education is a very important aspect of these conferences and meetings. For example, the National Conferences on Undergraduate Research (NCUR), organized separately from CUR, were conceived and first implemented by a CUR councilor, and several CUR councilors currently serve on the NCUR Board.

- In 1989 with support from the Research Corporation, CUR instituted a consulting service to advise chemistry departments about ways to improve their programs and increase their success rate in obtaining external grants. The program includes a visit to the department by two CUR consultants, who meet with faculty, students, and administrators and who later submit written recommendations. Followup visits are encouraged. Similar programs in other CUR Disciplinary Councils are being initiated.

- Beginning in the summer of 1990, CUR has offered to selected students Academic-Industrial Undergraduate Research Partnership (AIURP) fellowships in cooperation with leading American scientific companies. These fellowships provide $2500 to students to allow them to engage in research with faculty mentors at their home institutions normally during the summer after their junior year and, with most industries, provide these same students with the opportunity to work in the industrial sponsor's research laboratories during the summer preceding their entrance into graduate school.

- In 1983, CUR submitted a proposal to the National Science Board that was implemented as the NSF Research in Undergraduate Institutions (RUI) initiative (1984). After its first year the RUI program was reviewed by an ad hoc group that included among its four faculty members two chemists who were CUR councilors and a physicist who was to become a CUR councilor. The RUI program has become the model for "distributed funding" of science education through the NSF research directorates.

- Other CUR efforts to stimulate government interest in funding science at undergraduate institutions have included involvement with the development of the NSF Instrumentation and Laboratory Improvement (ILI) program, the NSF Research Experiences for Undergraduates (REU) program, and the NIH AREA program. CUR councilors helped to plan and chair sessions at the AREA workshop held in Bethesda, MD in March, 1990.

- The visibility of CUR to agencies and foundations has led to increased representation by undergraduate institution science faculty on important policy-making and funding committees. These have included advisory committees and review panels for the National Science Foundation, panel members for the National Institutes of Health, membership on the National Research Council's Board on Chemical Sciences and Technology, membership on advisory panels for private foundations, and service on boards of foundations and other scientific societies. The growth in these activities over the 12-year history of CUR have been enormous.

Organization

Initially formed in 1978 by chemistry faculty at private liberal arts colleges, CUR expanded to include public and private colleges and universities in 1983 and to include additional disciplinary councils in physics/astronomy and biology in 1985, geology in 1987, and the mathematical sciences in 1989. Prior to June 1989 the Council on Undergraduate Research consisted solely of councilors elected from among their colleagues by the current councilors. Committees were staffed by volunteers from among the councilors for the preparation and publication of the CUR directories and its Newsletter, for the arrangements and planning for National CUR Conferences, and for other assignments approved by the Executive Committee or the full Council.

In order to provide opportunities for increased numbers of faculty and administrators across the country to become directly involved in CUR and in order to provide a larger and more open forum for discussions of issues, CUR began in September 1989 to enroll members, who in turn elect councilors from within the membership. During the first year more than 1200 applications for membership were received, including blocks of applications from single institutions numbering as high as 85. A National Office with Dr. John G. Stevens as Executive Officer was opened in May 1991 with support received through grants received from the PEW Charitable Trusts and the Research Corporation and with contributions from undergraduate colleges and universities.

Testimony, Page 14
Professor Michael P. Doyle, Trinity University
July 11, 1991

EXHIBIT 3

Chemistry Graduates from Undergraduate Institutions Having Significant Undergraduate Research Participation

Year	224 Institutions Chemistry Graduates[a]	National Total[b]	Percentage of Total	Students in Research[c]
1985	3,070	9,679	32	1029
1986	2,742	9,295	29	1187
1987	2,768	8,848	31	1359
1988	2,722	8,372	33	1394

[a] Data from "Research in Chemistry at Undergraduate Institutions", Fourth Edition; Council on Undergraduate Research, B. Andreen and G.G. Wubbels, Eds., Feb. 1990.

[b] Data from American Chemical Society Committee on Professional Training, Exhibit 1.

[c] Employed full time in undergraduate research during the summer.

EXHIBIT 4

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PRELIMINARY RESULTS OF THE CUR UNDERGRADUATE RESEARCH SURVEY

Royce Engstrom

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In February the CUR Committee on Science Policy sent out a survey to all CUR members requesting information on their experience with the NSF-RUI (Research at Undergraduate Institutions) program. The survey was initiated to learn more about how well the RUI program is addressing the needs of investigators at predominantly undergraduate institutions. The results of the survey will be shared with the NSF along with recommendations from CUR based on results of the survey. In the present report, the information is presented without regard to subdiscipline; a follow-up report will look at correlations of responses according to subdiscipline. Approximately 1200 surveys were sent out and 692 were returned, for a return rate of 58%.

The first section of the survey concerned background data. The percentage of respondents by discipline was: Biology–25%; Chemistry–46%; Physics/Astronomy–16%; Geology–7%; Mathematics/Computer Science–4%; Administration–1%; and a few specifying disciplines other than those listed. Public institution respondents accounted for 26%, and private schools accounted for 62% (not all respondents answered every question, so the totals don't necessarily add to 100%). The respondents were from undergraduate only (69%) and Master's level (15%) institutions. Years as a full-time faculty member showed a binodal distribution, with peaks in the 0-5 years category and in the 20+ years category. One-fifth of the respondents were women and only 3% indicated belonging to an ethnic minority.

The percentage of respondents who have submitted a proposal to the NSF-RUI program was 35%. An additional 10% reported applying to regular NSF research programs. Of those individuals who have submitted to RUI, 64% indicated they had been successful (not necessarily on their first try). A total of 446 proposals were submitted to NSF-RUI (an average of 1.9 per submitter) and 221 of those (50%) were indicated as having been funded. The success ratio is significantly higher than that generally reported by the NSF (~30%) suggesting that the respondents to this survey (i.e., CUR members) enjoy a higher than typical success rate. Whether expressed in terms of people or proposals, the success rate is very favorable and should serve as a source of encouragement for those considering application.

An interesting correlation exists between the proposal pressure indicated above and the perceived financial needs of the investigators. The survey asked the respondents to indicate the level of annual funding required for their research program. The most frequently indicated range was

$5,000-15,000, checked by one-third of the respondents. The percentage of respondents indicating needs greater than $15,000 was 34%, notably similar to the percentage who have applied to NSF-RUI. Only 7% indicated the need for greater than $50,000 annually. It would appear that those who perceive the need for major funding are indeed applying for it, while those needing smaller amounts are receiving their support from other sources, including foundations and internal grants programs. There is perhaps a bit of the "chicken and egg" syndrome here. Is the *required* level of funding determined by the funding agency or does the required amount drive the choice of funding agency?

The number of students involved in the respondents' research program also showed a bimodal distribution, with 2 or 3 students being indicated by 39% and greater than five students indicated by 22%. The output in terms of publications per year was 0–19%; 1–46%; 2–20%; >2–10%. Only 16% of the respondents have reviewed for the NSF-RUI program.

The second section of the survey assessed the perceived impact of the NSF-RUI program. The survey presented several choices for the impact that NSF-RUI had at the respondent's institution. The respondents could check as many as applied. The results were: 33% said NSF-RUI had made no impact at their institutions; 47% said the program had encouraged research active faculty to expand their research in scope or productivity; 37% indicated RUI had encouraged new faculty researchers; 49% indicated it promoted student involvement; and 41% thought it encouraged students to pursue research careers (a highly encouraging result from the perspective of the pipeline issue). Approximately one-third thought NSF-RUI had increased the success rate and made more funding available at their schools.

An important goal of the RUI program might be to promote acceptance of research in undergraduate institutions by the larger research community. Of the respondents 48% thought that it had. An overwhelming 90% thought that RUI should be continued, a percentage far greater than that of people who have directly benefitted from the program.

The third section of he survey was completed by people who had never applied to NSF-RUI. Of those completing this section (449 respondents) the most frequently indicated reason for not applying (42%) was that their research was adequately funded by other sources, which is consistent with earlier information regarding required levels of funding. The second most popular response (35%) was that teaching and other duties have not allowed research at that level. The third most popular reason, selected by an alarming 25%, was that they had not been aware of the RUI program! Nearly a quarter (23%) stated they hadn't applied because they thought they wouldn't be funded. However, only 16% thought the success rate was too low to make it worthwhile.

Of those who have never applied, 30% plan to apply in the next two years, an encouraging sign. Help in the pre-submission stage, notably in the form of seeing examples of successful proposals, a pre-submission review by a CUR member, and consultation with a program officer, was perceived as being valuable in writing a more competitive proposal. Clearly, a role exists for CUR in helping potential applicants. For those who do not intend to submit to RUI, the most frequently indicated reason was lack of institutional support.

The final section was completed by people who have submitted to the RUI program (35% of the respondents). There was some question that in the early years of RUI, applicants may not have known that they were submitting to a special program. Such was not the case; 91% of the people applied specifically to the RUI program, and no one was confused as to whether or not they were making an RUI submission.

Respondents were asked a series of questions for both unsuccessful and successful submissions. (Note that many individuals would have answers in both categories.) Successful proposals were preceded by consultation with program officers at the NSF only slightly more often than unsuccessful proposals, 73% of the time for the former and 67% for the latter. Pre-submission reviews by a colleague were obtained with essentially identical frequency for unsuccessful and successful submissions, 38% and 39%, respectively. Neither group received a great deal of help on their campus in preparing the proposal; 21% of unsuccessful and 22% of successful applicants said they had. When asked if NSF reviewers adequately understood the proposed research, not surprisingly, all of the successful respondents said yes, while only 58% of the unsuccessful ones said yes. When asked if reviewers adequately understood the nature of undergraduate research, 54% of the unsuccessful respondents thought not, compared to 68% of the successful ones. Another divergence in opinion was indicated in asking if NSF reviewers adequately understood the importance of infrastructure impact in RUI proposals. Only 18% of unsuccessful respondents thought so, whereas 77% of successful applicants thought so. In both groups, half of the respondents contacted a program officer after the decision on their proposal was known. Approximately half of the unsuccessful proposers resubmitted or are planning to.

The results of the survey indicate several significant points that have bearing on future activities of CUR and on the RUI program. In terms of simply numbers of people, the 35% application rate would suggest that a substantial pool of potential proposal writers exists. Presumably, being CUR members, they represent a pool of faculty interested in undergraduate research and are probably more likely to apply than the general eligible population. However, the pool of people who feel they need to apply to NSF-RUI does not appear to be substantially greater than the pool that is currently applying. Indeed, the number of people indicating the need for the level of funding provided by NSF is very similar to the number applying. It would appear that the NSF-RUI program is responding responsibly to the pressure it is receiving. The success rate of the program, both in reality and in perception, is at a healthy level.

Prior to asking for increased resources in the NSF-RUI program, CUR's present emphasis should be on encouraging faculty and their administration to expand research programs to levels of activity that make use of greater amounts of support. Working to make local conditions more conducive to research appears to be of high priority. As for the NSF, they should consider ways of making the RUI program more visible to faculty, considering the number of respondents who didn't know of the program. NSF might also consider making the connection between RUI and infrastructure needs clearer to the reviewers of RUI proposals.

SECTION I:

1. What is your discipline?

174	Biology	7	Administration
315	Chemistry	3	Psychology
113	Physics/Astronomy	1	Engineering
45	Geology	1	Anthropology
29	Mathematics/Computer Sciences		

2. Type of institution:

176	Public	429	Private
476	Undergraduate only	103	Master's level

3. Years as a full-time faculty member

207	0-5	103	16-20
117	6-10	162	20+
99	11-15		

4. Gender 549 M 136 F

5. Are you a member of a federally-recognized ethnic minority?
19 Yes 665 No

6. Your research program requires an annual funding (direct costs only) of:

63	$0-1,000	134	$15,000-30,000
157	1,000-5,000	51	30,000-50,000
220	5,000-15,000	47	>50,000

7. Have you reviewed for the NSF-RUI program?

108 Yes 569 No

SECTION II:

1. At your institution, the NSF-RUI program has (check all that apply):

224	had little or no impact.
323	encouraged research-active faculty to expand their research in scope or productivity.
253	encouraged new faculty researchers to participate.
338	promoted the involvement of students in research.
279	encouraged students to pursue research careers.
153	increased the success rate of NSF research proposals.
218	made more NSF funds available.

2. Has the NSF-RUI program led to greater acceptance of research at undergraduate institutions into the larger research community?

331	Yes	35	No
295	Don't know		

3. Have you attended a presentation about NSF-RUI?

281 Yes 397 No

4. Is the NSF-RUI program announcement clear and useful?

473	Yes	30	No
154	Don't know		

If not, do you have suggestions for improvements?

5. Is it important that an NSF-RUI program be continued?

618	Yes	5	No
56	Don't know		

SECTION III:

1. The principal reasons why you have not applied are (check all that apply):

113	I was unaware that the program existed.
46	My research has been in an area not appropriate for NSF funding.
190	My research has been adequately funded from other (internal or external) sources.
53	I have been involved in funded collaboration at another institution.
12	I have not been interested in doing basic research.
156	My teaching and other duties have not allowed research at this level.
105	I didn't think I would be funded.
71	The success rate of the program has been too low to make it worthwhile.
74	I have received little or no institutional encouragement to apply.
86	Other

2. Do you plan to apply to the RUI program in the next two years?

133	Yes	81	No
225	Maybe		

3. If you intend to submit, what would help you write a more competitive proposal?

190	Availability of pre-submission review by a CUR member
113	Better institutional support for research
259	Seeing examples of successful proposals in my area
203	Pre-submission consultation with NSF program officers
114	Attending a presentation about the NSF-RUI program
21	Other

4. If you intend not to apply, what would change your mind?

25	Institutional expectation
90	Better institutional support, such as release time
29	Loss of research support
23	Availability of pre-submission review by a CUR member
56	Seeing examples of successful proposals in my area
24	Attending a presentation about the NSF-RUI program
28	Changes in the RUI program
11	Nothing
6	Other

SECTION IV:

1. For your **unsuccessful** RUI proposals:

53	Yes	27	No	Did you consult any research program officers at NSF before submitting? If so, were they helpful?
26	Yes	5	No	Did you consult anyone in the RUI program?
29	Yes	50	No	Did you obtain a pre-submission review from a colleague knowledgeable in your research area?
17	Yes	63	No	Did you receive significant help on your campus in the preparation of the proposal?
47	Yes	24	No	Did the NSF reviewers adequately understand the research you were preparing?
16	Yes	44	No	Did the NSF reviewers adequately understand the nature of undergraduate research?
9	Yes	41	No	Did the NSF reviewers adequately consider the special instructions regarding infrastructure impact?
37	Yes	36	No	Did you consult a program officer after receiving notification of reviews?
40	Yes	37	No	Did you resubmit or are you planning to?

2. For your **successful** RUI proposals:

102	Yes	35	No	Did you consult any research program officers at NSF before submitting?
32	Yes	100	No	Did you consult anyone in the RUI program?
54	Yes	83	No	Did you obtain a pre-submission review from a colleague knowledgeable in your research area?
31	Yes	105	No	Did you receive significant help on your campus in the preparation of the proposal?
131	Yes	0	No	Did the NSF reviewers adequately understand the research you were preparing?
97	Yes	17	No	Did the NSF reviewers adequately understand the nature of undergraduate research?
75	Yes	20	No	Did the NSF reviewers adequately consider the special instructions regarding infrastructure impact?
63	Yes	66	No	Did you consult a program officer after receiving notification of reviews?
35	Yes	96	No	Were you funded for substantially less than you requested?

APPENDIX A

THE ORIGIN OF UNDERGRADUATE RESEARCH AND ITS INTEGRATION INTO UNDERGRADUATE SCIENCE EDUCATION

Undergraduate research is a relatively new educational venture and, in all respects, is an American invention. Growing out of the fertile combination of an investigator in search of a problem with a problem in search of an investigator, *undergraduate research has become the most exciting educational development of the second half of the 20th century.* Its success is measured, in part, by the stimulation of this experience for students to enter graduate or professional schools, but its principal benefit is that it imparts to students a realistic assessment of the character of a discipline through the process of discovery.

Like a 16-year old who has just received a driver's permit, an undergraduate student has considerable enthusiasm but lacks experience. The student may have completed most of the basic courses expected for a major in the discipline but is not yet so sophisticated to know if a question that he or she might ask has already been answered. The faculty scholar, on the other hand, is an expert in at least one area of the discipline and understands what problems are ripe for discovery. When the scholar accepts the apprentice, a problem is identified and the approach to its solution becomes the framework of an undergraduate research experience. Initially, the scholar directs all aspects of the problem's development but, eventually, the student becomes the expert.

The origin of undergraduate research is difficult to assess, and there have been different directions taken in different disciplines. In the sciences, which have the longest tradition of undergraduate research, the actual visible beginning of these experiences occurred only after the Second World War. There were, of course, examples of individuals and institutions that engaged in these activities even during the nineteenth century, but they were isolated instances peculiar to certain institutions and to teacher-scholars who promoted such experiences for highly talented students. Even Harry Holmes, a distinguished scientist and Professor of Chemistry at Oberlin College, inferred in 1924 that research was a proper engagement for the college teacher, but not necessarily for the student. In responding to an earlier criticism of college teachers who engaged in research, Professor Holmes states (*1*):

> "A stimulating freshness and a feeling of authority come to the college teacher as he unravels the secrets of science. The teacher profits, the great body of science profits, and the pupil profits. The pupil then feels that he is near one of the fresh springs that feed the stream of knowledge into which he has been dipping.
>
> It is essential that the teacher do research work, i.e., he should comb the subject of chemistry from end to end for facts and for methods of exposition that will make such facts live and real to his students."

As an educational methodology, research was to be valued because it imparted excitement into what might otherwise be an exposition of dull facts. But the involvement of unsophisticated undergraduate students in this endeavor was not expected and, for most faculty in colleges and universities, considered impossible.

Undergraduate research had its beginnings in faculty research where students took on the role of assistant, setting up experiments, preparing starting materials, or looking after experimental animals, but they did not perform the actual experiment. To do so would have led to uncertainty in the results and their interpretation, because how could an untrained eye discern the complex nature of the experiment being performed? Yet in this pre-World War II era, students were involved in many laboratories, and they were watching the conduct of experiments and learning about the process of discovery. This was especially true in undergraduate institutions where junior and senior students were the principal workforce. In universities with graduate programs there was less need to involve undergraduate students; here graduate students were available and had as their principal objective the conduct of research.

Something extraordinary occurred during this period. Undergraduate institutions educated more students who went on to obtain graduate degrees in science than did many of their larger university counterparts which had graduate school programs. In its Report to the President in 1947 on Science and Public Policy, the President's Scientific Research Board observed (*2*):

> "Although some 90 universities grant all the doctor degrees in science, undergraduate work in science is scattered throughout our higher educational system. Less than half the doctors of science receive their undergraduate training in the same school that confers their advanced degree. The remainder complete their undergraduate work in about 600 other colleges or universities.
>
> Thus, the 90 university graduate schools depend in large part upon 700 schools, including their own, which grant bachelor degrees in science. These in turn depend upon science courses in many others of the total of 1,700 schools in the country. Many smaller institutions have, in the past, contributed scientists out of all proportion to the numbers of their students. Thus: During the years of 1936 to 1945, Furman University, Oberlin College, Reed College, and Miami University together graduated more students who later completed doctoral work in physics than did Ohio State University, Yale University, Stanford University, and Princeton University combined.
>
> Over the same period, Hope College, Juniata College, Monmouth College, St. Olaf College, and Oberlin College combined produced more candidates for doctor's degree in chemistry than did Johns Hopkins University, Fordham University, Columbia University, Tulane University, and Syracuse University, all together."

Why did this occur? We recognize now that research was a significant preoccupation at these colleges, and undergraduate students observed the challenges of investigation and the enthusiasm that was generated by discovery.

Just following the end of World War II, the Research Corporation designed a funding initiative, the Cottrell Grants Program, to provide incentive for scientists to return to colleges and universities rather than joining on-going industrial and federal research at the large central laboratories into which they had been "drafted" for the course of the War (*3*). Grants from the Research Corporation were provided to faculty in chemistry and physics departments for research in which they were engaged or about to initiate, and a significant fraction of these grants were awarded to scientists at predominantly undergraduate institutions. Not surprisingly, in those early years most of these Cottrell grants were received by faculty at institutions that already had a recognized tradition of research. But these grants, unlike contracts provided by the Office of Naval Research (ONR) at that time, made possible full time summer research for selected undergraduate students.

Faculty members who were performing research in the sciences during the summer needed assistants and, without the cadre of free labor available when classes were in session, found that student employment provided the necessary workforce. Funding available from the Research Corporation provided this flexibility to certain faculty. No longer limited by the time constraints of coursework, students become more intimately involved in actual experimentation. They learned the techniques and mastered observation with critical evaluation of results. By the end of the summer, these summer employees were well versed in experimental details and filled with the excitement of potential new discoveries. With the advent of the new academic year, faculty curtailed their research in order to prepare for classes, but their students, enthusiastic with experience from their summer research engagements, came into the laboratory with regularity to continue their experimentation. Out of this was borne the beginnings of undergraduate research in the sciences.

The next major leap in the development of undergraduate research occurred in the early 1960's when the National Science Foundation initiated the Undergraduate Science Education program which became their Undergraduate Research Participation (URP) program. In this post-Sputnik era, this country placed a high premium on encouraging students into careers in science and engineering, and the URP program was created with the belief that if you allow an undergraduate students to experience the challenges and excitement of discovery, their participation would become an addiction.

The success of the URP initiative during the 1960's can be measured in terms of the rapid increase in the numbers of students who obtained their Ph.D. degrees in the sciences (*4*) and in the comments of URP students who found that their undergraduate research experiences led them to careers in the sciences (*5*). The URP program had its greatest impact on students in biology, chemistry, and physics - so much so that by the early 1970's more students obtained their Ph.D. degrees in these fields than there were positions available to them. Grants awarded to public and private colleges and universities opened new vistas for many institutions without prior experiences in undergraduate research and, in many respects, the enterprise was institutionalized in the sciences during this period.

Although the largest single contributor to the development of the tradition of undergraduate research in the sciences, the National Science Foundation's Undergraduate Research Program was not the only initiative. Research grants to faculty awarded by the National Science Foundation and the National Institutes of Health were often used, in part, to support undergraduate research. The Petroleum Research Fund, administered by the American Chemical Society, encouraged undergraduate research through their Type B grants to faculty in undergraduate departments at colleges and universities. The Research Corporation continued its funding ventures and, in 1971, initiated its College Cottrell Science Program to support faculty and student research at private (now public and private) undergraduate institutions. Even organizations as diverse as the Argonne National Laboratory and Du Pont hired undergraduate students to undertake research experiences in their laboratories. Similar support mechanisms for undergraduate research did not exist in the social sciences, humanities, and the arts.

In part because of the excess supply of scientists in the early 1970's, various attempts were made to dismantle the URP program, but without success. Instead, its goals and targets were changed from year to year until 1981 when this program, along with the entire science education operation at the NSF, was terminated. Unfortunately, the URP program was lost at the same time that the number of new Ph.D.'s entering the mainstream of science who were U.S. citizens was declining to pre-1965 levels. Reconsideration of this impact, principally through a comprehensive study of undergraduate science, mathematics, and engineering education by a Task Force of the National Science Board (*6*), as well as efforts undertaken through the NSF's Chemistry Division, resulted in the resurrection of undergraduate research participation through introduction of the NSF's Research Experiences for Undergraduates (REU) program, now in its sixth year.

The very nature of undergraduate research requires a special talent in the preceptor. The problems undertaken must be significant but they must also be doable within a limited time frame, and students must be given the opportunity to develop the investigation. Often the research begun by one student is continued by another. In other approaches teams of students are engaged, each assigned to a particular aspect of a problem, or the preceptor and student approach the investigation together, each contributing to its development. No single model is appropriate to all investigators or all investigations.

Twenty years ago undergraduate research was limited in most institutions to students in their senior year, and the term "senior research" was commonly applied to this endeavor. The remnants of this are still seen in "senior honors projects" at many colleges and universities. However, such limitations may actually inhibit the development of students in a research program since their graduation abruptly terminates their investigations just when they are most capable of obtaining critical results. Instead, early entry into research allows students the luxury of learning about research, making mistakes, and understanding pertinent literature with time remaining to thoroughly investigate the problem. There is an intimacy of association that comes from intense involvement in a research program. For students who have tasted the excitement of discovery, their addiction continues after graduation.

Our experience at Trinity University, a liberal arts institution of 2300 students, exemplifies the importance of undergraduate research in the development of student careers in science. Unlike many institutions to which Trinity University is now compared, prior to the 1980's her science students entered medical school or industry rather than graduate school. Science was not her principal strength, and her alumni do not yet include members of the National Academy of Science. However the 1980's brought significant changes to Trinity that evoked an excitement for careers in science at a time when, nationally, student interest in the sciences was rapidly declining. For example, in 1989 Trinity graduates received seven National Science Foundation Graduate Fellowships, placing 14th among U.S. colleges and universities and universities in awards per capita.

The Department of Chemistry exemplifies the dramatic changes that have occurred. Between 1970 and 1985 an average of seven majors per year graduated, and fewer than one per year entered graduate school in the chemical sciences. By the end of the 1980's the number of chemistry majors had nearly tripled, an average of seven students per year was entering graduate school in chemistry or biochemistry, and in one two-year period five Trinity University chemistry majors received the prestigious National Science Foundation Graduate Fellowships - nearly 5% of the total awarded nationally.

What are the factors that contributed to this change? Prior to 1985 fewer than 5 students per summer were engaged in undergraduate research. In the summer of 1990, 41 students were performing research with chemistry faculty, and one-third of them had only completed their freshman year of studies; and for the summer of 1991 nearly the same number of students were engaged in this activity. Funding for these programs has come from research grants, mainly from the National Science Foundation, a site award from the NSF-REU program, and contributions from private foundations. All of the students who have undertaken careers in the chemical sciences since 1985 have credited their decision to their undergraduate research experience.

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MICHAEL P. DOYLE

Professor Michael P. Doyle is a nationally recognized research scientist and chemical educator. Born and raised in Minneapolis, Minnesota, he received his B.S. degree from the College of St. Thomas in 1964 and his Ph.D. from Iowa State University in 1968, where he was a U.S. Public Health Service (NIH) Predoctoral Fellow. He was a postdoctoral associate and instructor at the University of Illinois at Chicago before he began his academic career at Hope College in the Fall of 1968. Rising rapidly through the academic ranks, he was advanced to the level of Professor in only six years, and in 1982 he was appointed the first Kenneth G. Herrick Professor at Hope College. In 1984 he moved to Trinity University as the first Dr. D.R. Semmes Distinguished Professor of Chemistry.

Dr. Doyle has received wide recognition for his scientific and educational achievements. He received a Teacher-Scholar Award from the Dreyfus Foundation (1973-78), he was presented with the Chemical Manufacturers Association Catalyst Award in 1982, and he was the third recipient of the American Chemical Society Award for Research at Undergraduate Institutions sponsored by the Research Corporation (1988). He is the co-author of two textbooks for organic chemistry and one monograph. He has served as a member of the Research Corporation's Cottrell Program Advisory Committee (1978-83), and he is currently a member of the Research Corporation's Board of Directors. He was the first faculty member from a liberal arts college to be appointed as a member of the National Science Foundation's Chemistry Division Advisory Committee (1982-85), and he is currently a Member of the National Research Council's Board on Chemical Sciences and Technology (1989-92). His professional activities have extended from involvements with the International Union of Pure and Applied Chemistry, where he is Titular Member and Secretary of the Commission on Physical Organic Chemistry, to service on numerous review panels and workshops of the National Science Foundation, National Institutes of Health, and National Academy of Science. His activities in the American Chemical Society include appointment to the Committee on Professional Training, which approves chemistry departments for student certification, election to the Executive Committee for the Division of Organic Chemistry, and appointment as Chairman of the ACS Committee for the Membership Affairs (1990). Since his move to Trinity University in 1984, he has presented more than 100 invited lectures at professional meetings, universities, and chemical industries.

Dr. Doyle and his students have coauthored more than 130 research publications during the 22 years since he began his academic career in 1968. Undergraduate student co-authors number 90, and half of these students are credited with two or more publications. Counting only undergraduate coauthors, 45 have either received their Ph.D. degree or are completing the requirements for their Ph.D., 10 have received their M.S. degree, and 30 have obtained or will obtain their M.D. degree. The research areas that have captured student interest extend from the chemistry of nitrogen oxides in biological systems, electron transfer reactions, and diazonium ion chemistry to organosilane reductions and selective oxidations. Dr. Doyle's current research interests include the design of catalysts for highly selective chemical transformations and the development of new synthetic methods involving carbenes.

Dr. Doyle was one of the founding members of the Council on Undergraduate Research, its first President (1978-83), the Editor of its Newsletter (1978-present), and the Chairman of this organization (1978-89). He has been Chairman of the Executive Committee for the National Conference on Undergraduate Research, and he was Conference Chair for the Third National Conference held at Trinity University in 1989.

Campus Life

Craig Borland for The New York Times

Prof. Michael P. Doyle of Trinity University holding a bottle containing his creations, the Doyle catalysts. The catalysts may be capable of synthesizing purer pharmaceuticals and pesticides than current manufacturing techniques allow. With him were Michael Jarstfer, who helped write a paper on the project, and Bridget Brandes and Amy Kazala, right, who worked on the catalysts in the laboratory.

Trinity U.

Students as Catalysts in a Chemical Change

SAN ANTONIO — With the aid of undergraduate students, a chemistry professor at Trinity University has developed a class of catalysts that may be capable of synthesizing purer pharmaceuticals and pesticides than is currently possible.

Named for their creator, Michael P. Doyle, the Doyle catalysts, when used to promote a chemical reaction, can manufacture only the chemical substance needed, without producing other substances that can cause unpleasant side effects.

Nancy Mills, a chemistry professor at Trinity, said the Doyle catalysts could be used in the production of pesticides like Permectrin, which is effective against houseflies and mustard beetles. They have also synthesized pharmaceuticals like imipenem, an antibiotic similar to penicillin.

The Federal Drug Administration and the Environmental Protection Agency have indicated that they may eventually require pharmaceuticals to be "optically pure isomers," Professor Doyle said. That refers to a condition where only the specific drug needed is produced in the synthesizing. His catalysts would enable manufacturers to comply with expected Federal regulations, said Professor Doyle, who is the D.R. Semmes Distinguished Professor of Chemistry.

'A Chance to Discover'

Research Corporation Technologies, which has a contract with Trinity and other colleges and universities to develop faculty inventions, has a patent application for Doyle catalysts.

Professor Doyle's research is distinctive as much for the way it was conducted as for its scientific content: The bulk of the work is generally performed by Trinity undergraduates, who often publish the appropriate papers in scientific journals.

"The research provides students challenges, insights, opportunities for discovery and an opportunity to decide whether it is a career choice," Professor Doyle said. "More important, it is a chance to discover."

Among Trinity students who have worked with Professor Doyle are Bridget Brandes, a junior, and Amy Kazala, a sophomore, both chemistry majors from San Antonio.

Ms. Brandes and Ms. Kazala, who became involved with the Doyle catalysts project while still at Incarnate Word High School here, spent the last two summers studying the catalysts, sometimes working up to 12 hours a day, seven days a week in the laboratory. During the school year, they work about 12 hours a week on the Doyle catalysts in the lab.

They, along with Professor Doyle and four others, have written a paper on the Doyle catalysts that is to be published this month in Tetrahedron Letters, a chemistry journal. The other authors are Michael Jarstfer, a junior chemistry major from San Antonio, and three former students: Linnette Watkins, who is at the University of Notre Dame, Roland Peters, studying at the Massachusetts Institute of Technology, and Cassandra Eagle, a professor at Williams College in Massachusetts.

"At Trinity, because it's primarily undergraduate, you get a lot of hands-on," Ms. Brandes said. "You're not always fighting graduate students for the equipment."

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Mr. **Wolpe.** Thank you very much.

Congressman Nagle has not yet arrived, so I will introduce our final witness on this panel, Dr. James Swartz, Associate Professor of Chemistry and Chair of the Science Division at Grinnell College in Iowa. Dr. Swartz.

TESTIMONY OF DR. JAMES SWARTZ, ASSOCIATE PROFESSOR OF CHEMISTRY; CHAIR OF THE SCIENCE DIVISION, GRINNELL COLLEGE, GRINNELL, IA

Dr. **Swartz.** Mr. Chairman, thank you for the opportunity to be here today.

I left yesterday afternoon four undergraduate research co-workers and six minority high school students working on research projects. In addition, I left a number of curriculum development projects on which I am working.

These are the types of activities identified by Project Kaleidoscope which lead students to learn and pursue careers in science. In my 11 years at Grinnell, I have come to realize the crucial interaction of teaching and research in the undergraduate enterprise.

I firmly believe that those two areas, often thought of as competitors, are critically linked to the quality of undergraduate education in science. They are the two legs upon which the enterprise balances, and it is very difficult to stand steady upon only one.

The Grinnell chemistry program is unusual in that it has continued during a time of dramatic national decline to graduate a large number of chemistry majors, over 85 percent of whom go on to earn graduate degrees in science. It has also been unusually successful in attracting NSF support.

I believe those two observations are linked. At the majority of colleges in the Nation, we have programs for which inadequate support has left them unable to muster truly effective programs.

In Appendix A of my written testimony, I briefly describe the Grinnell chemistry program and list critical NSF support. As I look around, I find almost no part of that program which has not been touched by an NSF-supported instrument or development project.

I am happy that one of your committee members, Congressman Nagle, has had the opportunity to visit Grinnell and see first-hand what that support has accomplished. We are grateful to you, the U.S. Congress, and the National Science Foundation, for that support.

You might note from that list, however, that there are many grants for curriculum development, but there are none within the past 10 years. One might assume that we have recently been less successful in the grants process. But the fact is, for the past 10 years, there have been no general curriculum development programs at the National Science Foundation. It was an auspicious moment late this spring when the National Science Foundation announced its first curriculum grants in more than a decade.

The Neal Report, a report issued by the National Science Board in 1986, called for a substantial increase in undergraduate programs at the National Science Foundation. It recommended an increase in budget for undergraduate programs, exclusive of Research in Undergraduate Institutions, to what would have been 6.8

percent of the National Science Foundation budget, or about $200 million in 1991. This year, the level of funding is about $86 million, less than half of what the Neal Report recommended.

Let me tell you a story about a recent National Science Foundation grant in the Instruments and Laboratory Improvement program for the chemistry department at Grinnell College. Two new faculty members decided to prepare a proposal for the purchase of a visible ultraviolet spectrophotometer.

The proposal anticipated that this spectrophotometer would be used in experiments in the introductory chemistry course and in a junior level instrumental analysis course. The award for $11,166 was made in May of 1990. The college provided the required 50 percent match and the instrument was delivered late in June.

The principal investigators soon began working with that instrument, to learn to use it and design the final details of an experiment to be used in the fall in the introductory course. One of them quickly realized that a project one of his research students was working on would greatly benefit from use of the instrument.

I developed a project for minority high school students using this computer-controlled instrument. By fall, the infection had spread, and every single class the Chemistry Department offered included at least one experiment designed to make use of that spectrophotometer.

A biology faculty member took notice of what was going on and convinced me that the two of us should submit a proposal to a private foundation for three additional identical instruments that the two departments would share for use in their introductory courses. A number of visitors to the chemistry department observed what was going on, and two have since called me for details, because they intended to acquire a similar instrument.

My point here is that an $11,000 investment by the National Science Foundation has in one year had a large impact on a large number of students and faculty from more than one department, and in fact from more than one institution. And most of that impact was unanticipated.

This ILI program has received glowing reviews, but has had level funding for the past three years. Since scientific equipment costs escalate at about 10 percent per year, that's a real cut of 30 percent. The Neal Report recommended funding of this program at about three times the current budget.

The Neal Report laid out the problems and the skeleton of reform of undergraduate science education. Project Kaleidoscope put meat on those bones. Although there is substantial evidence that undergraduate science education is in trouble, the Project Kaleidoscope report describes a number of programs which are successful.

I urge you and the National Science Foundation to work with the undergraduate community to mount an effort appropriate for this issue and vital to our national interests. We have much work to do, but it is essential work. The dangers of not acting, risking the science education enterprise, are far too great to miss this opportunity.

[The prepared statement of Dr. Swartz follows:]

Testimony of Jim Swartz, Chair of the Science Division,
Grinnell College, Grinnell, Iowa

Before The

Investigations and Oversight Subcommittee
House Committee on Science, Space, and Technology

July 11, 1991

I am Jim Swartz, Associate Professor of Chemistry and Chair of the Science Division at Grinnell College in Grinnell, Iowa. I arrived at Grinnell College in 1980 after doing undergraduate work at a community college and a small state college in California, graduate work at the University of California at Santa Cruz, and two years of postdoctoral research at CalTech. I have recently served as Chair of the Chemistry Department at Grinnell College, and now serve as Chair of the Science Division, which includes the departments of Biology, Chemistry, Mathematics, Physics, and Psychology.

In my eleven years at Grinnell I have come to realize the crucial interaction of teaching and research in the undergraduate enterprise. I firmly believe that those two areas, often though of as competitors, are critically linked to quality undergraduate education in science. They are the two legs upon which the enterprise balances, and it is very difficult to stand steady upon only one.

I have found that learning is a personal activity. Students need to feel that they can make the material theirs. My most effective teaching is that which takes place with my research coworkers or in research-like experiences in courses. Establishing a dense of community among the students and faculty is critical. Students get most excited when they understand that they are part of the discovery process and have an active role, rather than the passive one they all too often have come to expect.

I have also realised the importance of National Science Foundation support for the chemistry program at Grinnell College. In Appendix A, I briefly describe that program and list crucial NSF support. As I look around I find almost no part of that program which has not been touched by a NSF-supported instrument or development project. I am happy that one of you, Congressman Nagle, has had an opportunity to visit Grinnell and see first-hand what that support has accomplished. We are grateful to you, the U.S. Congress, and to the NSF for this past support and look forward to a productive future.

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We meet today because there are ominous signs that undergraduate science education in the U.S. is troubled. Not only are there far fewer students completing science majors, but there are a number of indications that instruction is of poor quality and ineffective. The Project Kaleidoscope report does an excellent job of laying out the problems and an array of solutions, citing exemplary.programs where those solutions have been successful. I believe that our problems are linked to the fact that, during the late 1970's and early 1980's, the NSF phased out essentially all programs dealing with undergraduate education, and educational development lacked leadership and funding. Recent work of the NSF and Congress (this Committee being a prominent participant) has begun to establish an infrastructure from which we might rebuild excellence in undergraduate science education. I will recommend to you that NSF substantially enhance its undergraduate programs in the USEME office. Additional programs and funding are needed in:

instrumentation,
course and curriculum development, and
faculty development.

The Problems

Allan Bromley, Head of the Office of Science and Technology Policy and Advisor to the President, is quoted as follows by THE SCIENTIST (July 23, 1990) in response to a question about whether "... universities need to improve their teaching of science":

> "I do not consider that as one of our major problems... I'm much more concerned about the quality of science and math teaching at the elementary and high school levels than I am about the quality at the undergraduate level. Students in colleges and universities are much more able to cope with less-than-superb teaching, and if they have been taught at all well, they should be doing a remarkable amount on their own."

I come before you to take issue with this statement and indicate what I believe some of the problems to be with undergraduate science education and how the NSF and liberal arts colleges can play a role in the solutions to those problems.

We are all aware of the "pipeline problem", that we are not graduating sufficient American scientists to sustain a prosperous and technologically advanced society and economy. I will not dwell upon this, but move on to focus on other symptoms of a troubled undergraduate science education enterprise.

We set the stage for students to become scientists before they enroll in college, and if we do a poor job in pre-college education it is almost impossible to effectively educate those students as scientists at the college level. There is, however, a hemorrhage from the pipeline at the college level. Over half (54%) of college freshmen with a strong interest in science or engineering do not complete baccalaureate degrees in science or engineering (R.C. Alkinson, Science, 1990, 248, 425. Somehow the college science curriculum either lacks the ability to keep students interested, is too discouraging, or is too difficult for most students who are interested in science. This hemorrhage is an indicator of poor quality instruction; students are voting with their feet.

Science graduates are not representative of the population of the United States. Although the percentage of women science majors has increased substantially in the past 15 years, the source of that increase is due more to the decrease in the number of men majoring in science than an increase in the number of women. Blacks make up 12% of the population of the U.S., but only 4% of science bachelors degree recipients. In 1986-7 less than 90 institutions graduated more than two American Blacks with degrees in physical science. In most years fewer than ten Blacks or Hispanics receive PhD degrees in chemistry. As members of these under-represented groups become a larger fraction of our workforce, the fact that they are not pursuing science careers in representative members compounds the pipeline problem. We must also admit that our education system is flawed if for no other reason than that it fails to give an equal opportunity for all to pursue science careers.

Another critical failing of our educational system is the question of science literacy. Only one of 15 U.S. adults and one of five U.S. college graduates is literate in science (J.D. Miller, Daedalus, 1983, 112, 29). Colleges and universities are failing in the charge to educate citizens who can properly function in a scientific and technological society.

We also must note that colleges and universities are responsible for educating the nation's pre-college teachers. Our primary and secondary school teachers consider science to be the area in which they are least qualified to teach (I.R. Weiss, 1977 National Survey of Sci., Math., & Soc. St. Educ., Wash. DC: U.S. Gov't Pri.Off., 1978). We must provide our future pre-college teachers a sound background in science and technology and a sense of excitement about and appreciation of the importance of those disciplines, if we hope to have a scientifically literate general population and to provide the background and motivation to students to pursue further study.

The points above are the symptoms; what is wrong? The introductory courses are the critical ones. It is those courses which discourage the largest number of those students who come to college intending to become scienctists. Those courses are, for the most part, the only ones taken by students who do not major in science, i.e. the students who become pre-college teachers and who will (we hope) be our educated citizens. In the introductory courses we pursue a model not much changed from the early 1960's. During the "Sputnik" era we had a large number of well-prepared students entering our colleges, and we persuaded many to major in science. The role of introductory courses was to cram as much

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information as possible into the courses and to select the "best" students to go on for additional studies in science. Introductory biology, chemistry, mathematics, and physics became known as "weed-out" courses. We assumed that scientists could best make scientific decisions for the nation, and there was little perceived need for science literacy in the general population.

Today we have more poorly prepared students entering the university, and a much smaller proportion of those students interested in science, and a greater need for scientific literacy among our citizens. We, however, cling to the same model of teaching, have crammed more and more information into those courses, and "weed out" all but the most persistent and adept. The material in those courses is almost exclusively focused upon preparing students for the 'next course' rather than for a life as an educated citizen, and, thus, has little relationship to their experiences. We have, somehow, not recognized that we must alter introductory courses to attract students to science and to provide some science literacy to all. We need courses which are nourishing rather than herbicidal.

Sheila Tobias has recently published a very revealing study of introductory courses in science. ("They're Not Dumb, They're Just Different", Research Corporation, 1990). She placed highly qualified, highly able college graduates who had been science avoiders in college, as "ringers" in standard introductory chemistry and physics classes. Those students not only studied the material of the course, but reflected upon the course structure, content, and style. Those "ringers", for the most part, did very well but found the courses disconnected, impersonal, and ineffective at either teaching science or inducing any interest in science among the students. The participants found that neither they nor the other enrollees in the courses could come up with answers to the questions: "What are we learning?" and "Why are we learning this now?"

The Causes

So here we have the problem. Our old model of science education is not working in that it is (1) not producing enough students who plan to pursue careers as scientists; (2) not engaging a representative sample of the population; (3) not providing a sound background and excitement about science for our future K-12 teachers; and (4) not producing a scientifically literate population.

There are a number of causes of these problems, but one which we can address here today is a lack of Federal leadership and support for undergraduate science science education. NSF support for college science has withered dramatically during the decades of the 1970's and 1980's. **The total NSF support at the 30 colleges represented by the Independent Colleges Office in 1968 and 1987 has declined by 53% over these 19 years, a decline of 86% in constant dollars.** (These colleges would be a good sample

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of the Carnegie-classified category, Liberal Arts I, which includes 140 independent colleges and two public ones. Data taken from "Federal Support to Universities and Colleges", FY 1968 and FY 1987, National Science Foundation, Washington, DC: U.S. Government Printing Office, 1969 and 1988.) Even more dramatically, the median school in these arrays shows a decline of 78% in NSF support (93% in constant dollars), which indicates that the very scarce support is being concentrated in the stronger colleges. This data indicates the large and serious erosions of Federal support of science education in an important sector of baccalaureate education. It is ironic that this group, despite the lack of curricular development and scholarship support from the NSF, has done better than any other class of institutions in maintaining high productivity of scientists. ("The Future of Science at Liberal Arts Colleges" and "Maintaining America's Scientific Productivity", Oberlin College, 1985, 1987)

In sharp contrast, **NSF support at the research universities has continued apace.** For the 100 universities that were the largest recipients of Federal support, **the NSF contribution went from $179 million in 1968 to $1,069 million in 1987, an increase of 497%.** The median school increased 401%, indicating a slight concentration of support in the more successful universities. In constant dollars, the net increase in NSF support was 82% at those institutions.

If one were looking around the science education landscape for a large direct cause of the crisis in science education, none would be larger than this dramatic shift in Federal spending priorities away from a balance of education and research to almost exclusively research.

This record of inadequate support has had a corrosive effect on college and university faculty. Many college faculty who went into their jobs in the 1960's and 1970's did so when NSF science education support promised reasonable means of sustaining a career as a teacher/scholar. That vision became a chimera in the late 1970's and early 1980's as science education support at NSF ground to a halt. College science faculty began to use their summers to teach summer school, paint their houses, and find odd jobs. Similarly, research university faculty learned that there was no professional future in science education. One could not get money to take the time and to acquire the resources to follow up on curricular ideas. Furthermore the peer reviewed grants process is one of the few ways in which college and university faculty can show evidence of excellence in professional activity. When there is no funding, there is no peer review of curricular or professional development, and the local reward system (recognition, raises, and promotion) fails to recognize curricular development a a substantial professional activity. So the ideas for improvement were ignored and gradually ceased to come. Research became the only game in town for university faculty, and, practically, the only professional engagement for college science faculty.

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In contrast to the situation of support for faculty development in the field of science education, the National Science Foundation has done a far better job of supporting faculty development in the area of research. Excellent programs include Research Opportunity Awards, Research at Undergraduate Institutions, and Research Experiences for Undergraduates. I do strongly support (and have myself taken advantage of) these research oriented programs and am convinced they have a crucial role in developing excellence in undergraduate education. These research programs, however, affect only a very small fraction (about one in 300) of faculty at undergraduate institutions. While I believe these programs to be excellent, but under-funded, I would like to concentrate here on support for curricular development. I assert that excellence in education cannot be achieved by only excellence in research. Excellence in curriculum design and content and in instruction is also absolutely necessary. The 1980's program of the National Science Foundation sent a message that research was the only game in town. That, unfortunately, was the wrong message. Again, what we need is both legs, curricular innovation and research, on which to balance an excellent program.

In March, 1986 a task force of the National Science Board, chaired by Homer Neal, released a report, "Undergraduate Science, Mathematics, and Engineering Education" (referred to as the Neal Report) which presented a thorough study of undergraduate science education in the United States. The study found that serious problems, especially concerning quality, had developed during the proceeding decade. The report described undergraduate education in the sciences, mathematics, and engineering as "the essential bridge the schools and the nation's apparatus for research and development" and suggested efforts to reform it must be "nationwide...and will require participation by public and private bodies at all levels." **The Neal Report concluded that it was critical that the National Science Foundation retake a "meaningful leadership role" in undergraduate science, mathematics, and engineering education.**

The Federal government and NSF in particular must realize that they need to participate as leaders in restoring a balanced set of values in science faculties. The formula for reform is to provide professional rewards for science faculty who maintain strong and distinguished commitments to both research and education, and to recognize as lesser contributions those that ignore one or the other. NSF's primary mission, enunciated in its charter, is to stand squarely for the unity of research and education in science. We have begun to see a substantial improvement at NSF, with the institution of some successful programs including Instrumentation and Laboratory Improvement (ILI), Undergraduate Course and Curriculum Development (UCC), and Undergraduate Faculty Enhancement (UFE). What we need is to sustain and enhance those efforts.

The Solutions

In 1986 the Neal Report recommended a $100 million increase in the annual appropriation for undergraduate education. Neal recommended that funding through SEE (now EHR) at a level which would have been 6.8% of the NSF budget in 1986. That corresponds to about $199 million in 1991 (these numbers will be referred to as the adjusted Neal recommendations). The Current Plan for USEME funded and target programs related to the Neal Report is $86.8 million (the total for undergraduate programs less Research at Undergraduate Institutions, which was not addressed in the Neal recommendation). The funding available is, thus, less than half of what was conservatively recommended in this National Science Board report. Without a substantial additional effort we will continue to fall further and further behind in our attempts to achieve excellence in undergraduate science education. An annual investment of less than 2% of the cost of the SSC or less than 10% of the current year budget for the space station, Freedom, is affordable and essential to demonstrate leadership of the entire undergraduate science education operation of the nation. If we do not make such an investment we may not have competent scientists to develop, construct, and operate these new technologies.

Instrumentation. One of the first programs established under the newly founded Undergraduate Office of Science, Engineering, and Mathematics Education (USEME) was ILI. That program funds the purchase of laboratory instrumentation for use in instructional (as opposed to research) laboratories. Although the program funds go exclusively to purchase instrumentation, the program is an indirect and rather effective form of curricular development.

Program dollars are highly leveraged. A minimum of 50% of the funding must come from non-federal sources. Furthermore, no funds are provided to support personnel to actually develop experiments making use of the new instrument. (This year the USEME office expects to fund a few proposals in a new program, Leadership in Laboratory Instruction, which do provide some personnel support.) The ILI program has been evaluated several times and has received glowing reviews.

Not only are the dollars spent in the ILI program highly leveraged due to matching and the fact that faculty time for implementation comes without any Federal support, there are other leveraged aspects to the program. Other faculty at the institution will notice the instrument, learn to use it, and devise unforseen curricular changes. Furthermore, students and faculty involved in research projects will undoubtedly use the instrument. Faculty may (either formally through publication or informally) tell their colleagues at other institutions of their successes and encourage them to mount similar efforts at their home institutions.

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Let me tell you the story of a recent ILI grant to the Grinnell College Chemistry Department. Two new faculty decided to prepare a proposal for a visible-ultraviolet spectrophotometer. The award for $11,166 was made in May of 1990. The College decided to use internal funds to provide the match, and the instrument was delivered in late June. The grant proposal anticipated that the spectrophotometer would be used in experiments in the Introductory Chemistry course and in a junior level, Instrumental Analysis, course. The principal investigators soon began working with the instrument to learn to use it and to design an experiment for use in the introductory course in the fall. One of them quickly recognized that a project that one of his research students was working on would benefit greatly from the use of the instrument. Soon after this student began to work, several other students noticed that their research would benefit from experiments using the spectrophotometer. I was developing a series of projects to be conducted by high school students (in a program to maintain and stimulate interest of highly qualified minority students in science), and I designed a study using this computer controlled instrument. By fall the infection had spread and every class the Chemistry Department offered included at least one experiment which made use of the spectrophotometer. This summer our 28 chemistry research students are using the instrument nearly all day and most of the evening. A biology faculty member took notice of what was going on and the two departments decided to submit a joint proposal to a private foundation for the purchase of three additional spectrophotometers to be shuttled between departments for use in the introductory courses in both programs. My point here is that an $11,000 investment by NSF has, in one year, had an impact on a large number of students and faculty from more than one department, and that **most of that impact was unanticipated!**

I find three problems with the ILI program. First, there are substantially more qualified projects than can be funded. This program has received level funding for the past three years. (The numbers in the USEME budget appear to have increased; however funds for ILI grants for PhD granting institutions which were previously charged to the Research and Related accounts are now charged to the USEME account. Thus, the budget line shows an increase when no increased funds for the program have been available.) Since scientific equipment costs inflate at about 10%/year, there has been a real decrease of roughly 30% in the past three years. Secondly, much curricular innovation does not occur because many faculty simply do not have the time to make the best use of the instrumentation. I believe that the new Leadership program has made an auspicious start in this area, but the USEME office has had to carve off funds from the standard ILI program to support this initiative, and they expect to fund only a small fraction of the proposals received. Thirdly, many institutions find the burden of 50% matching funds larger than they can afford. Institutions must take on the burden of increased maintenance and repair costs (about 5-10% of the original cost/year). Many simply cannot afford half the cost of

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the instrument in addition to those ongoing costs. These costs hit less affluent institutions (including many historically Black colleges and universities) particularly hard. NSF should consider decreasing the required match from 50% to 35%. Congress should provide a substantial increase in the ILI budget to adjust for inflation, to support the new Leadership program, and to decrease the required matching funds. The Neal Report recommended $94 million (adjusted) for what are essentially the ILI and Leadership programs. The current plan is $27 million, less than one third of the recommendation.

Curriculum. Another area of critical need is direct curriculum development. It was an auspicious moment late this spring when the National Science Foundation announced its first curriculum grants (for general science curricula) in more than a decade. The Undergraduate Course and Curriculum (UCC) program currently focuses upon curricular development in introductory science courses. (There are two separate programs which have awarded a small number of fairly large grants, one focused on calculus instruction and one on engineering instruction.) In this, the first year of the program, the community responded with a flood of ideas. The USEME office received 714 proposals requesting $260 million, but could only fund a total of $9.25 million in projects. It is clear that there are ideas for curricular reform. There are, however, not enough resources available to support a comprehensive effort. There is a significant risk in operating a program with such a low success rate. Once individuals get the word that the odds of being funded are only about one in 28, they will be discouraged from spending the time (typically 60 hours) to prepare and submit a proposal, and innovation dies.

Funding is not the only problem in the curriculum area. The program, as it is now designed, only supports curricular innovation in the introductory courses. It does not explicitly address the issues of science literacy or curricula beyond the first year. These two areas are also filled with problems and ripe for reform. The Alfred P. Sloan Foundation has recently concluded a ten year project, The New Liberal Arts Program, aimed at improving scientific, quantitative, and technological literacy of liberal arts students. Funding in that program was limited to a few highly selective liberal arts colleges and several historically Black colleges and universities. NSF should take the opportunity to take the baton from this program and to broaden the impact from the rather narrow set of institutions.

The ILI program is really the only program which now supports curricular innovation at the advanced undergraduate level, and it does so only indirectly. While I recognize that the most critical area for reform is at the introductory level, UCC should be expanded to address problems at other levels as well.

Finally, I would like to address the question of style of curricular innovation and reform. It is often tempting to single out a few select, highly visible institutions, fund them at high levels, and expect them to devise an excellent curriculum which everyone would adopt. **To do that would be to repeat the mistakes of the centrally planned economies.** That is to say that a few have such good ideas that all should adopt them. The problems here are manifest. First, it assumes that there are one or several curricular models which will work everywhere. There is absolutely no evidence that this is the case. I am confident that the needs for curriculum are different at CalTech, Grinnell College, the University of the District of Columbia, Clark-Atlanta, and the University of Wisconsin. The other issue here is that curriculum is personal. Faculty do their best teaching and students their best learning when they have invested themselves. Just as in economic development, the most successful work comes out of an entrepreneurial spirit, when many individuals have the opportunity to try their own ideas. Some of those ideas will be outstanding, noticed by others, and emulated, but the key to excellence is to promote individual efforts. If we adopt the centrally planned economy approach we doom ourselves to the degree of success which we now see results from that approach. My point here is that we should support many smaller projects rather than a few large 'model' projects. We also need to allow some projects to develop just as local improvements, not requiring them to be national models. Small projects aimed simply at improving courses for the students at the home institution will benefit those students, and may, in fact, become model programs, but we typically have trouble recognizing which projects will be such successes at the very beginning. How many of us recognized that Intel, Apple Computer, or WalMart were likely to be so successful that we wagered a substantial portion of our resources upon them in the start-up phases?

The Neal Report recommended funding of $24 million (adjusted) for curriculum efforts. The Current Plan is $14 million, a little over half of the recommendation. The NSF should expand curricular reform efforts to include science literacy, upper level courses, and local course improvement.

Faculty Development. A third productive area for NSF programs is faculty development. It is essential that faculty, throughout their careers, keep up to date in the rapidly changing fields of science and remain excited about their work. The NSF has a number of excellent programs for faculty development focused upon the research environment. There is only one program which funds non-research activities, the Undergraduate Faculty Enhancement program. That program supports seminars and workshops to assist faculty in maintaining their competence in their disciplines, and to broaden their expertise, but here again only a small fraction of eligible faculty (about 1%) are supported.

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NSF needs to substantially broaden its support of undergraduate faculty development programs. The Acting Director recommended in his November 16, 1990 report, "The Infrastructure of Undergraduate Education", to your full committee initiatives in this area including:

> supporting science and engineering faculty to take leaves of absence to study pedagogy, or to combine research and educational improvement in such a leave.
>
> support for faculty professional activities at their own schools and involving their own students that includes subjects beyond traditional disciplinary research.
>
> support for postdoctorals, two year college teachers, and high school teachers to work with college faculty mentors on projects that combine teaching and research.

I wholeheartedly endorse these suggested initiatives and hope that NSF can find resources to initiate them. The Neal Report recommended funding of $24 million (adjusted) for faculty development programs. The Current Plan is $4 million for the UFE program, only about one sixth of the recommendation.

Facilities. I should make a brief comment on facilities. It is, of course, essential that appropriate facilities be available for any strong program to evolve and sustain itself. There has been considerable recent discussion of the poor state of U.S. scientific research and instructional facilities. The NSF has mounted a small effort to deal with renovation of research and research training, but not instructional, facilities. I was involved in making recommendations to and reviewing the guidelines for that program, and submitted a successful proposal. I would like to compliment the NSF on establishing what I believe is an excellent program. Critical in that process was the grouping of institutions so that a variety of types of could compete against other like institutions. I want to make clear here that there was no entitlement for anyone, but a chance for the NSF peer review process to choose excellence in different types of institutions. The program has been very small, but I believe it is a highly successful model upon which to build.

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Concluding remarks

The Neal Report laid out the problems and the skeleton for reform of undergraduate science education. Project Kaleidoscope has put meat on those bones. There is substantial evidence that there are severe problems in undergraduate science education. The Project Kaleidoscope report, however, describes a number of programs which, in a variety of settings, are successful. I urge you and the National Science Foundation to work with the undergraduate community to mount an effort appropriate for this issue so vital to our national interest. One issue critical for Congressional action is to increase the funding available for undergraduate programs administered by USEME to be consistent with the recommendations of the Neal Report. At a minimum, doubling of the budget for undergraduate activities is in order. We have much work to do, but it is essential and rewarding work which will have great rewards. The dangers of not acting, risking the science education enterprise, are far too great to miss this opportunity.

APPENDIX A
An Example of the Crucial Role of NSF Grant Support in the Evolution of the Grinnell College Chemistry Department

The Chemistry Department currently numbers six faculty, has two staff, produces 15-20 B.A. chemistry majors per year from an enrollment of 1270, and has about 130 each year in the introductory course. The Table summarizes NSF grant support in the Chemistry Department since 1964. As one reads through the list it may be noted that virtually no area of involvement of the Department was untouched by NSF support. All of the equipment, whether acquired for "research" or "instructional" purposes does duty for both, which is an efficient use of funds. Funds for improvement of facilities were hard to find in this period, but the College used an NSF-CAUSE grant in 1979-82 in part for this purpose - to remodel and enlarge a space for a biochemistry laboratory, a rapidly changing area of chemistry. The Department also did a fair bit of improving of curricula via the CAUSE, LOCI, and several instructional equipment grants (ISEP, CSIP, and ILI). The research grants are a form of faculty development at a rather high level of development, but the several URP grants (and lately an REU grant) and sabbatical leave support grants are direct faculty development projects.

The Department in 1990 finds itself well equipped with state-of-the-art instrumentation, mostly of a more modest design than might obtain at a research institution but adequate for publishable research. NSF has furnished crucial help in almost every case in acquiring this instrumentation. This in itself is a strong spur for faculty professional activity, to student research, and to up-to-date experimental work in courses. Equipment is not the only thing that is needed, but it has valuable catalytic effects on many other areas of endeavor in a small non-doctoral department.

This record of successful grant activity was not put together without some discouragement. A few of the proposals were successful the first time around, but most of them required persistence. In particular, the large CAUSE grant went through two failures, the URP grant in 1978 was preceded by three failures, and most of the research grants to individuals were preceded by one or more failures. It is extremely important to see this. Those grants when finally acquired made a huge difference in the evolution of the Department. Not only was important work done, but the members of the Department were forced to think through what they wished to do and to find a rationale for doing it that persuaded their peers. The value of that is probably equivalent to the value of the grant itself.

The Chemistry Department at Grinnell College according to many statistical measures and qualitative judgments of peers is in excellent shape. It has probably gotten relatively stronger in its science education capacity over the past 30 years. But it should not be missed that the crucial agent of that improvement and of the robust current condition has been NSF support chiefly through the Science Education Directorate but also through the research directorate. If one were to subtract NSF support, not much science education competence would remain. Grinnell minus about two-thirds of its NSF grant support would represent most college chemistry departments in the U.S. today.

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Summary of NSF-Supported Science Education Projects in the Chemistry Department of Grinnell College 1964-91

Project	Total Cost	Year	NSF Program	NSF Contribution
50 Student projects in 12 years	$ 68,600	1964-1971, 1973, 1978 1980,1981	Summer Research NSF-URP	$ 68,600
Sabbatical Leave Research - Science Division	$240,000	1967-71	NSF-COSIP	$ 180,000
Sabbatical Leave Research - Prof. L.E. Erickson at Univ. of North Carolina	$ 7,000	1968-69	NSF-SFF	$ 7,000
Research Grant - J.D. Danforth 5 student projects	$ 30,000	1968-73	NSF	$ 30,500
13 Student projects	$ 25,000	1970-71	NSF-SOS	$ 18,970
Research Grant - L.E. Erickson 6 student projects	$ 25,100	1970-73	NSF	$ 25,100
Biochemistry Laboratory Equipment	$ 10,000	1972	NSF-ISEP	$ 5,000
60 MHz CW Nuclear Magnetic Resonance	$ 30,000	1974	NSF-Chem. Instr.	$ 20,000
Spectrofluorometer	$ 10,600	1978	NSF-ISEP	$ 5,300
UV-VIS Spectrometer	$ 21,750	1979	NSF-69A	$ 11,600
Biochemistry/Molecular Biology and Equip.	$183,000	1979-82	NSF-CAUSE	$ 122,000
60 MHz FT Nuclear Magnetic Resonance Spectrometer	$ 40,000	1980	NSF-2Y/4Y	$ 25,000
Physical Chemistry Lab. Curriculum	$ 13,000	1980-82	NSF-LOCI	$ 13,000
3 Student projects	$ 10,000	1981	NSF-SI-URP	$ 8,500
Gas Chromatograph/ Mass Spectrometer	$ 63,000	1981	NSF-Chem. Instr. and ISEP	$ 25,000
Sabbatical Leave Research - G.G. Wubbels at Univ. of Leiden (Neth.)	$ 19,560	1981-82	NSF-SFPD	$ 19,560

Electrochemistry Equip.	$ 22,500	1982	NSF-2Y/4Y	$ 22,500
Sabbatical Leave Research - Elliott Uhlenhopp at Univ. of Calif., San Diego	$ 8,500	1984-85	NSF-ROA	$ 8,500
Nanosecond Laser Transient Spectrometer	$ 46,800	1985	NSF-CSIP	$ 23,400
Research Grant. - G.G. Wubbels 15 Student projects	$108,100	1986-88	NSF-RUI	$ 108,100
300 MHz Nuclear Magnetic Resonance Spectrometer	$220,000	1986	NSF-RUI	$ 95,300
Liquid Chromatograph/ Diode Array Detector	$ 30,000	1986	NSF-RUI	$ 8,500
Fourier Transform Infrared Spectrometer	$ 48,000	1987	NSF-CSIP	$ 24,000
Sabbatical Leave Research - J. Swartz/ U. of Minn.	$ 20,000	1987-88	NSF-ROA	$ 20,000
Low Freq. NMR Probe	$ 7,000	1989	NSF-RUI	$ 7,000
Research Grant - G.G. Wubbels 18 student projects	$130,500	1989-91	NSF-RUI	$ 130,500
Diode-array UV-Vis spectr.	$ 22,332	1990	NSF-ILI	$ 11,166
30 Student projects	$ 120,000	1990-92	NSF-REU	$ 120,000
Remodeling of Chemistry Research Facilities	$ 250,000	1991-93	NSF-RFO	$ 250,000
Total				$1,419,096

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Mr. **Wolpe.** Thank you very much. I want to express my appreciation to the witnesses for some excellent testimony, both verbally and in the written statements in which you are able to elaborate at greater length with specific recommendations.

I want to commend you, Dr. Sullivan, and all your colleagues who worked on Project Kaleidoscope for a really excellent job. We are fortunate to have several representatives from the Project Kaleidoscope executive and advisory committees testifying today, and you have drawn on a number of excellent resources for your study, not the least of which is our own chairman, George Brown, who was referred to in the testimony a moment ago.

I understand you have submitted your report to the National Science Foundation along with a letter to Dr. Massey which summarizes your recommendations. We of course look forward to hearing NSF's comments on Project Kaleidoscope later in this hearing.

[The letter mentioned above follows:]

Project Kaleidoscope
Suite 1205-ICO
1730 Rhode Island Avenue N.W.
Washington, D.C. 20036

May 1, 1991

Dr. Walter E. Massey, Director
The National Science Foundation
Washington, D.C. 20550

Dear Dr. Massey:

On behalf of my colleagues on the Executive and Advisory Committees of Project Kaleidoscope, it is a pleasure to communicate with you in your first weeks as Director of the National Science Foundation. Project Kaleidoscope has been an extended effort involving presidents, deans, and faculty in mathematics and the natural sciences from the nation's liberal arts colleges and other predominantly undergraduate institutions. We received NSF support from the Education and Human Resources (EHR) Directorate — Division of Undergraduate Science, Engineering, and Mathematics Education (USEME), with additional grants from the Exxon Education Foundation, The Pew Charitable Trusts, the Kellogg Foundation, and the Camille and Henry Dreyfus Foundation.

Our charge was to outline a plan for the coming decade for undergraduate science and mathematics education in the liberal arts setting; our report presenting this plan of action, "What Works: Building Natural Science Communities," will be published in June. We recognize that the NSF must take the leadership role if the nation's problems in undergraduate science and mathematics are to be addressed, and present here for your consideration our recommendations that pertain specifically to the NSF. This letter will be included in the report and thereby become part of the formal record of Project Kaleidoscope.

We began our work in the fall of 1989 convinced that undergraduate science and mathematics must be strong if the challenges facing this country are to be met — if we are to have 1) an educated citizenry that is scientifically and technologically literate, 2) adequate numbers of well-equipped scientists and mathematicians for the nation's academic and research communities, and 3) scientifically competent and confident primary and secondary school teachers. A strong undergraduate sector is critical if this nation is to attract more women and minorities into science and mathematics.

Both the forthcoming report and the Project Kaleidoscope National Colloquium, held at the National Academy of Sciences on February 4 and 5, 1991, have been based on our experience and analysis of undergraduate programs that succeed in attracting and sustaining student interest in science and mathematics. Over 600 persons participated in the National Colloquium, representing colleges and universities from across the country, federal and private funding agencies, and educational associations. Dr. Frank Press, in his welcoming remarks, called it perhaps the most important gathering at the Academy in twelve months. Our report will include summaries of colloquium activities, including presentations by Dr. James L. Powell, Congressman George E. Brown, Jr., and Dr. D. Allan Bromley.

We applaud your commitment to ". . . strengthen the research base and infrastructure and improve science education and opportunities for all students . . ." as expressed in your recent Congressional testimony. We believe liberal arts colleges and other predominantly undergraduate institutions offer an ideal venue for reform efforts. Because of their size — small enough to make change possible, their *institutional commitment* — strong enough to make change likely, and their proven *record of productivity*, these institutions provide an excellent place from which to start the reform of undergraduate science and mathematics.

This reform should be based on a clear understanding of *what works*. We are convinced that science and mathematics education works wherever it takes place within an active community of learners, where students work collaboratively in groups of manageable size, and where faculty are deeply committed to teaching, devoted to student success, and convinced that all students can learn. It works where learning is active, hands-on, investigative, and experiential, and where the curriculum is rich in laboratory experiences, steeped in the methods of scientific research as it is practiced by professional scientists. This approach works for women, for minorities, for all students.

We are convinced that the success of predominantly undergraduate colleges in attracting, retaining, and graduating persons who go on to science and mathematics careers and who become scientifically literate citizens can be traced directly to this approach. You and your colleagues in the federal sector can be assured of our intent to be active partners in the national effort to strengthen science and mathematics at all educational levels. Four initiatives must receive highest priority in the immediate future if this approach is to be implemented in schools and colleges across the country. The recent FCCSET report is consistent with these initiatives.

INITIATIVE I. REFORMING THE INTRODUCTORY COURSES IN UNDERGRADUATE SCIENCE AND MATHEMATICS.

INITIATIVE II. SUPPORTING THE INTEGRATED TEACHER/SCHOLAR ROLE OF UNDERGRADUATE SCIENCE AND MATHEMATICS FACULTY.

INITIATIVE III. MAKING DISCIPLINARY CONTENT AND ACTIVE LEARNING CENTRAL TO THE EDUCATION OF K-12 TEACHERS OF SCIENCE AND MATHEMATICS.

INITIATIVE IV. DEVELOPING PARTNERSHIPS FOCUSED ON STRENGTHENING UNDERGRADUATE SCIENCE AND MATHEMATICS.

You will find specific recommendations for the NSF in relation to these initiatives in the accompanying exhibit. Although each is described separately, there is a strong relationship among these four initiatives — each dimension of the undergraduate effort must be considered integral to the whole. Efforts will not succeed if the reform of introductory courses is seen as separate from faculty enhancement activities, or if teaching and research are seen in competition with each other rather than as integrated responsibilities of the undergraduate faculty member. Furthermore, such efforts will be unproductive if advances in scholarship, technology, and pedagogy are not linked explicitly to programs for instrumentation acquisition and curriculum development.

In each of these initiatives, careful attention must be paid to under-represented groups in science — women, minorities, and handicapped — whose lives would be enriched by greater achievement in these areas, and who would in turn make a significant contribution to the lives of us all. This is one reason why, in Project Kaleidoscope, there is strong participation of faculty and administrators from Historically Black Colleges and Universities. Everyone has much to learn from their successes.

We do not expect the NSF to meet all the needs of undergraduate science and mathematics with grant support; however, we do look to the NSF to set the parameters by which reform efforts are to be undertaken, evaluated, and disseminated, and to do this in concert with the community it seeks to serve. The graduates of institutions for which we speak have made and can continue to make a significant contribution to the nation's scientific infrastructure — as citizens, and as members of the academic and scientific communities. The liberal arts colleges need to be at the table as policies and programs affecting undergraduate science and mathematics are considered. Congressman Brown emphasized this in his presentation at the Project Kaleidoscope National Colloquium, saying that reform efforts need financial support, but more important, they need an environment in which people collaborate in working toward mutually agreed-upon goals.

Our work builds on that of many others — the National Science Board (The 1985 Neal Report), the work of the "Oberlin 50 Colleges," the Council on Undergraduate Research, and the member institutions of The Independent Colleges Office — in the effort to help focus attention on the significance of the undergraduate academic experience in the science and mathematics pipeline. We recognize that considerable progress has been made, and are grateful to Drs. Bassam Shakashiri, Luther Williams, and Robert Watson for their leadership. However, one challenge you face is to bring a clearer focus to undergraduate activities within the Foundation. We look to the NSF to mount a sustained effort to strengthen undergraduate science and mathematics, and urge you not to abandon programs before they have had time to work. It takes time to accomplish effective change.

Beyond the initiatives presented here, there are further issues we believe must be addressed.

First, a concern is that current discussions — about the relationship of teaching and research, about balance between big science and little science, as well as balance between educational sectors — may not be informed by a clear understanding of what the predominantly undergraduate institutions have to offer. An analysis of the membership of NSF policy and advisory boards reveals that predominantly undergraduate institutions generally, and liberal arts colleges specifically, are under-represented, given the disproportionate contribution these institutions make to the national scientific and educational enterprise. To meet the national goal to attract more students into science and mathematics, NSF support must be available to all sectors of the collegiate community that have documented productivity in the education of scientists and mathematicians. If this is to be accomplished, representatives of all such sectors must participate as policies and programs are developed.

Equally important, data analysed by NSF should highlight sector by sector productivity — disaggregated by gender and race — as a basis for establishing policies and programs. Procedures should be put in place to gather such data systematically, within the context of grant applications and reports, as well as through normal research mechanisms. Over the long term, these would help to document the effectiveness of reform efforts across the board and within the different sectors.

A final concern relates to facilities. The magnitude of the facilities deficit at predominantly undergraduate institutions is known to us all. If needed reforms are to be made in introductory courses and meaningful research opportunities are to be provided for faculty and undergraduate students, our facilities must accommodate such reforms and programs. It is hard to imagine how predominantly undergraduate institutions across the country are going to tackle successfully the pressing facilities problem without the NSF as a major player. With its peer review process exerting quality control — eliminating pork barrel decisions about academic priorities — and with the leverage its support can bring as colleges seek funds for facilities from other sources, a facilities program at NSF is critical. The recent NSF program for facilities modernization (RFO) was a promising beginning; we regret that this program is not included in the current NSF budget request. Of particular value in the RFO program was the formula distribution of funds between educational sectors. This was a clear signal that each sector had much to contribute to the total national effort; this model should be continued as further NSF programs for facilities and for major instrumentation are planned.

We urge the NSF to take a leadership role on the facilities issue, and join with Congress and the nation's colleges and universities to determine how to balance the infrastructure needs of all sectors of the research and research-training communities. The current plan to provide support for major research instrumentation rather than for research and research-training facilities does not address the need for better balance in NSF support to the different sectors of the community. It would be particularly helpful if the NSF would establish a multi-year facilities program linked to course and curriculum development and the acquisition of instructional instrumentation. Colleges and universities could then build such an NSF program into their long-range plans for facilities modernization. A study of the needs of the undergraduate sector for teaching, research, and research-training facilities would assist in developing the necessary long-range plan.

Finally, let me say that all of us involved in Project Kaleidoscope look forward to working with you and your colleagues at the National Science Foundation to make this nation's science and mathematics enterprise one of the highest quality. We thank the National Science Foundation for the support that made our work possible. Warm regards.

Sincerely,

Daniel F. Sullivan
Chair, Project Kaleidoscope Executive Committee
President, Allegheny College

Exhibits: A. Initiatives and Recommendations

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Massey Letter
EXHIBIT A
Page 1

INITIATIVE I. REFORMING THE INTRODUCTORY COURSES IN UNDERGRADUATE SCIENCE AND MATHEMATICS.

◆ **Recommendation #1:** The FY 1993 Budget Request for Instructional Laboratory Equipment be increased to $33 million, with a continuing focus on introductory courses.

◆ **Recommendation #2:** The FY 1993 Budget Request for Course and Curriculum Development include an $18 million outlay for local improvements in introductory courses at colleges and universities, in addition to the outlay for comprehensive programs.

◆ **Recommendation #3:** These programs be housed, along with their budget authority, within USEME, with an administrative structure that addresses the need to coordinate programs and policies with the research directorates.

The transformation of introductory courses must be NSF's highest undergraduate priority over the next five years. A significant body of research and our own experience confirms that the first year of college is the point of a critical drop-off in numbers of students in science and mathematics courses.

Students acquire and confirm lifelong beliefs and attitudes about science and mathematics in their introductory courses. This is where they make the decision whether or not to major in these fields, whether or not to take further courses, whether or not it is important to be literate on science issues. When these courses are dull, consisting mainly of lectures and canned labs, when they keep students isolated and passive, and press on at breakneck speed for the sake of "coverage," when they are too big and faculty members are unwilling to support each student's progress, they slam the door on the positive attitudes toward science. The final formal experience of learning science is often one of frustration and failure. Courses labeled *introductory* turn out to be *terminal*.

Our own experience validates that the introductory course can be a pump instead of a filter. Introductory courses can give first-year students the pleasure of discovery and the opportunity to construct personal understanding of science and mathematics at a critical stage in their academic career.

The recommended funding levels given above are consistent with those in the Neal Report; they address the demonstrated interest at the local level to strengthen undergraduate programs, and they establish a more equitable balance in NSF support for research and education programs.

Several hundred proposals, requesting over $200 million, were submitted to NSF for the first competition of the expanded Course and Curriculum Program, excluding proposals in Calculus and Engineering. The available funds through USEME, for all disciplines, was $14 million. A similar level of interest is evident in the Instructional Laboratory Improvement (ILI) program, where each year proposals reviewed request almost four times the funds available from NSF. We are particularly concerned that the College Science Improvement Program (CSIP) — the ILI component for predominantly undergraduate institutions — has been level funded for the past three years.

We ask you and your colleagues to consider a new program for departmental development of lower-division courses — one that would include support for instrumentation, development time and supplies for new curriculum, and faculty expansion and enrichment opportunities. Such a new program would emphasize again the integral relationship of each of the parts of the undergraduate academic experience in science and mathematics. Moreover, it would establish a means by which the experiences and resources of predominantly undergraduate institutions can serve as models for strengthening undergraduate science and mathematics.

In all of these programs, one criterion in determining grants should be the impact that an award will have on attracting and sustaining student interest in science and mathematics. A more targeted focus on courses for science literacy for all students should be announced, perhaps supported jointly between the NSF, the National Endowment for the Humanities, and the Fund for the Improvement of Post-Secondary Education. The means by which the impact of the proposed projects would be evaluated and by which their activities would be disseminated to the larger community should also be a review criterion.

Parallel to the recommendations of adequate funding levels and expanded programs, we recommend that the NSF establish a budget line

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Page 2

item for these programs, and hold a single office accountable for coordinating the distribution of grant funds. We recognize NSF's current rationale for cross-directorate programs; however, funds "targeted" within research directorates for undergraduate programs have often become the first casualty when available funds for research are not adequate. If we are to move with all deliberate speed to achieve the essential reformation in introductory courses at the undergraduate level, there must be within NSF a strong, highly visible office where these programs are initiated, integrated and coordinated. We believe that office should be USEME.

INITIATIVE II. SUPPORTING THE INTEGRATED TEACHER/SCHOLAR ROLE OF UNDERGRADUATE SCIENCE AND MATHEMATICS FACULTY.

- **Recommendation #4:** The Research Experiences for Undergraduates (REU) program be expanded so that more students from liberal arts institutions can be provided the opportunity to do research at their home institutions and to allow REU Supplements to be used flexibly to support student-faculty research in predominantly undergraduate institutions, especially for those groups under-represented in science.
- **Recommendation #5:** The programs for undergraduate faculty supporting professional growth, including research and other scholarly activity, be strengthened and broadened.

The hands-on, discovery-based, laboratory-rich approach we advocate requires that teaching faculty be actively engaged in scholarship. Faculty active in scholarship foster a culture that enhances the community of learners; these faculty are often the most productive leaders in curriculum reform and laboratory improvement efforts, locally and nationally. Faculty active in scholarship are the most effective role models for students, and faculty-student research partnerships have been shown over and over to be a critical pump in the career pipeline. The distribution of revised Important Notice#107, which requires researchers to document the ". . . effect of the proposed research on the infrastructure of science and engineering . . ." was a welcome step in recognizing that teaching and research should be integrated activities in the nation's colleges and universities.

We strongly support the REU program. However, because of the level of funding, only a small fraction of Site awards presently can be used to support students at their own institutions. This has discouraged significant numbers of highly qualified departments at undergraduate institutions from applying. Just as graduate departments use this program to recruit students to attend their graduate programs, undergraduate departments should be given the resources to use this program to recruit students into science and to retain them in science, mathematics, and engineering. The most successful graduate students are those who have a solid grounding in research techniques — who know what science is about.

The on-campus research programs of undergraduate faculty are supported through the NSF Research in Undergraduate Institutions (RUI) program. Maintaining and enhancing this valuable program is critical to the overall effort of strengthening the undergraduate academic experience. Given its distributed nature, strong oversight of RUI by a single office must be reinstituted to ensure that the importance and distinctive characteristics of undergraduate research continue to be recognized. We further recommend that you and your colleagues consider a simpler, streamlined award system for small-scale individual grants for undergraduate faculty. In addition, we recommend investigation of a modified program of start-up grants for undergraduate faculty, with criteria similar to those within the current Presidential Young Investigator Program, but at a level of support more appropriate to the needs and scale of research of faculty at predominantly undergraduate institutions.

We recommend further that the NSF establish a faculty development program that would support faculty exchanges between strong undergraduate institutions. In our studies we have found many successful teacher scholars in undergraduate institutions who can serve effectively as mentors and role models for colleagues at other undergraduate institutions. A program of faculty exchanges would provide important opportunities for joint curriculum development based on disciplinary, technological, and pedagogical advances. It would also assist in the development of partnerships working together toward the

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common goal of strengthening the undergraduate experience in science and mathematics. This award would parallel the current ROA program which enables undergraduate faculty members to do research at major universities.

The Neal Report recommended that the NSF spend $17 million by 1991 for programs focused on the enrichment of undergraduate faculty. The 1992 budget request for the Undergraduate Faculty Enrichment program, though increased over past years, is $6 million. This is inadequate. We take 400 as the base number of science-active undergraduate institutions. If the NSF is to have an impact at such institutions across the country, support for faculty enrichment programs must be expanded.

INITIATIVE III. MAKING DISCIPLINARY CONTENT AND ACTIVE LEARNING CENTRAL TO THE EDUCATION OF K-12 TEACHERS OF SCIENCE AND MATHEMATICS

- **Recommendation #6:** NSF priorities for the pre-college sector include encouraging colleges to redirect the structure and content of their teacher preparation programs to focus more directly on science and mathematics — utilizing an active, investigative, hands-on, content-based approach.
- **Recommendation #7:** NSF support a wider range of pre- and in-service activities for K-12 teachers, making use of the resources of *all* colleges with strong undergraduate programs in science and mathematics.

The single most important determinant of what elementary and secondary students learn in science and mathematics is how much their teachers know. Teacher preparation must include substantial, deep exposure to the content of subjects they will eventually teach. Teachers for the nation's K-12 community must have pre-service and in-service involvement with a hands-on, laboratory-rich, active learning experience with science and mathematics. This must be the way they are prepared in their undergraduate courses, another reason why NSF's first undergraduate priority must be reform of introductory courses.

In setting NSF priorities for K-12 programs, we urge you to recognize that undergraduate colleges, particularly those in the Carnegie Liberal Arts I classification, graduate high percentages of their students with majors in science and mathematics. These colleges, whose faculty are committed to the hands-on approach to learning, are natural sources of a substantially increased stream of properly educated science and mathematics teachers. These colleges are also excellent resources for the development of new materials for science and mathematics at the pre-collegiate level.

A large number of the colleges for whom we speak have entered into formal and informal partnerships with schools, bringing teachers to campus as research associates, and providing opportunities for teachers to gain new understanding about disciplinary advances and pedagogical approaches. It is clear from the workshops at the Project Kaleidoscope National Colloquium, that the potential is great for effective collaboration in faculty/teacher development opportunities and in the design of new materials for the elementary and secondary levels. These cooperative opportunities should be expanded, including their incorporation into REU projects, and expanding the ROA program to include K-12 teachers. We see education as a "seamless web," and the undergraduate sector as a key strand in the web.

INITIATIVE IV. DEVELOPING PARTNERSHIPS FOCUSED ON STRENGTHENING UNDERGRADUATE SCIENCE AND MATHEMATICS

- **Recommendation #8:** The NSF provide opportunities for regular national and regional colloquia to discuss what works in undergraduate science and mathematics education.
- **Recommendation #9:** NSF guidelines outline specific criteria relating to partnerships between schools and colleges, colleges and universities, and colleges and the private sector, focusing on faculty and curriculum development activities, evaluation and dissemination.
- **Recommendation #10:** Discussions about the proposed super computer highway include linking undergraduate science and mathematics faculty so that they can communicate regularly about research and teaching interests and have access to regional and national computing centers. Pre-college teachers of science and mathematics also should be linked to this highway.

It is clear that each sector of the science and mathematics education community has a unique contribution to make in addressing national goals; it is equally clear that we can accomplish more by working together than by working separately. The NSF has the ability to develop and sustain such working partnerships on a national basis, and to model within its own structure how such partnerships can be developed and sustained.

The success of many of the current networks supported by the disciplinary organizations, educational associations, private foundations, and corporations, demonstrates that there are significant numbers of persons who are ready and prepared to work together to strengthen the nation's scientific and educational enterprise. The Project Kaleidoscope National Colloquium was another strong demonstration that there is a growing national consensus about what works in science and mathematics and a commitment to get on with the task of improving the programs for which we are responsible. We recommend that the model of the Project Kaleidoscope National Colloquium, bringing together institutional teams — including presidents, deans, faculty members and development officers — be considered in the planning of further colloquia.

Level of NSF funding is not the only way to identify strong programs. The networks to be developed should include representatives from all segments of the educational community. These networks should have at their center those colleges and universities that have a demonstrated productivity in undergraduate science and mathematics.

As one example, with support from the Kellogg Foundation, there was a large representation at the National Colloquium from the Historically Black Colleges and Universities. Their contribution during the colloquium was significant; equally significant, we hope, are the connections that were made for cooperative efforts in the coming months and years.

Tables: Federal Support

Table 1. FCCSET Committee on Education and Human Resources FY 1992 Budget Matrix ***(dollars in millions)***

EDUCATION LEVEL/ MAJOR PROGRAM AREAS	FY 92 BUDGET REQUEST	AGENCY									
		NSF	ED	DOE	DOD	DOC	NASA	DOI	HHS	EPA	USDA
UNDERGRADUATE FORMAL & INFORMAL	100.0%	27.7%	3.4%	6.3%	36.9%	0.4%	5.2%	1.8%	14.7%	0.9%	2.6%
Program Evaluation /Assessment	100.0%	—	—	74.1%	—	—	—	0.0%	25.9%	—	—
FOUR-YEAR FORMAL TOTAL	100.0%	37.4%	4.8%	—	32.1%	0.5%	2.5%	1.0%	17.8%	0.1%	3.7%
Faculty Preparation/Enhancement	100.0%	99.4%	—	—	—	—	—	0.2%	—	0.4%	—
Curriculum Development, Total	100.0%	87.6%	8.7%	—	—	0.3%	2.4%	0.7%	0.2%	0.1%	0.0%
Curriculum materials	100.0%	81.6%	13.0%	—	—	0.4%	3.5%	1.1%	0.3%	0.1%	0.0%
Laboratory Equipment	100.0%	99.9%	—	—	—	—	—	—	0.1%	—	—
Comprehensive (Org. Reform)	100.0%	31.6%	—	—	17.4%	—	4.3%	1.4%	13.5%	—	31.9%
Student Incentives	100.0%	12.6%	5.1%	—	51.0%	0.8%	2.5%	0.7%	27.3%	0.1%	0.0%
Direct Student Support	100.0%	12.6%	5.1%	—	51.0%	0.8%	2.5%	0.7%	27.3%	0.1%	0.0%
Bridging Programs	—	—	—	—	—	—	—	—	—	—	—
Other	100.0%	48.0%	—	—	—	—	5.7%	35.9%	10.3%	—	0.0%

Taken from FCCSET-EHR Report

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Table 2. FY 1988, 1989, and 1990 Actual Expenditures, 1991 Current Plan for NSF Undergraduate Programs *(dollars in thousands)*

PROGRAM	APPROPRIATION FY to EHR		APPROPRIATION To R&RA by Directorate*						TOTALS	
			BBS	CISE	ENG	GEO	MPS	STIA	R&RA	NSF
Instrumentation & Laboratory Improvement (ILI)	88	11500	0	0	0	0	0	0	0	11500
	89	16000	957	625	3608	459	1728	0	7387	23387
	90	15802	2120	739	1487	830	0	0	5176	20978
	91	23000	0	600	2000	0	1400	0	4040	27040
Undergraduate Curriculum & Course Development (UCC)	88	2000	0	0	1000	0	0	0	1000	3000
	89	3977	0	74	1696	0	1106	0	2876	6853
	90	4000	0	3778	5109	0	1017	0	9904	13904
	91	11000		2835	2030	0	1000	0	5853	16853
Undergraduate Faculty Enhancement (UFE)	88	3000	0	0	0	0	0	0	0	3000
	89	3000	0	0	0	0	0	0	0	3000
	90	2900	0	0	0	0	0	0	0	2900
	91	4000								4000
Research Careers for Minority Scholars (RCMS)	88	0	0	0	0	0	0	0	0	0
	89	0	0	0	2	0	0	1823	1825	1825
	90	3470	0	0	0	0	0	0	0	3470
	91	6600	0	0	0	0	0	0	0	6600
Research Experiences for Undergraduates (REU)	88	0	2543	1258	2748	1650	3451	0	11650	11650
	89	0	3649	1696	2766	1548	4135	249	14043	14043
	90	0	4105	1721	3290	1572	5158	295	16141	16141
	91	0	4000	1776	3300	1700	4100	0	14876	14876
Research in Undergraduate Institutions (RUI)	88	0	7407	556	930	2224	5007	0	16135	16135
	89	0	8989	898	1158	2410	5211	49	18715	18715
	90	0	9129	1277	884	3365	5615	2	20272	20272
	91	0	5000	825	1000	2500	5200	0	14525	14525
Research Opportunity Awards (ROA)	88	0							1500#	1500
	89	0	630	71	133	135	653	54	1676	1676
	90	0	540	80	539	110	674	88	2031	2031
	91								1500#	1500
Career Access, NSFNet, and Other	88	850	0	100	0	0	0	0	100	950
	89	2612	0	1092	0	1039	0	0	2131	4743
	90	3767	110	2070	0	1250	0	0	3430	7197
	91	8000			6550	1000			7550	15900
Total Funding	88	17350	9950	1914	4678	3874	8458	0	30385	47735
	89	25591	14225	4466	9363	5591	12833	2175	48653	74244
	90	29939	16004	9665	11309	7127	12464	395	56954	86893
	91									101,296

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* R&RA figures do not add horizontally because not all totals are apportioned to the listed directorates.

# Not attributed in FY88.

## Not yet apportioned.

NSF data.

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Mr. WOLPE. I would like to begin with a general question, to all the panelists. If I understand the thrust of your testimony, and even the implied thrust of the Project Kaleidoscope testimony, there are really two keys to the success that liberal arts undergraduate institutions have enjoyed in this area. One is the emphasis upon teaching, upon a self-conscious focus on how best to teach. But the second is the integration of hands-on research opportunities for both faculty and students, the integration of that with the teaching process itself.

There has been a national debate that has gotten some visibility in recent months about what is happening at other institutions across this country, and recognition that somehow there has been such a preoccupation with the research dimension of higher education that the teaching mission appears to have been greatly sacrificed, at least at many larger institutions.

I would be interested in whatever thoughts you gentlemen might have as to means, institutionally, of providing a different set of incentives, to begin to get greater balance into the teaching-research mix that takes place, and ways in which Federal program activity might help in restoring that kind of balance.

Dr. Sullivan?

Dr. SULLIVAN. Let me try to answer a very good and complicated question. One is tempted sometimes to be glib in a response, but it is a complicated question.

The best answer I would give about what we need to do and what might be done, especially in the large universities, really came from the provost of MIT at a meeting that David Sanchez called not long ago, of a number of presidential colleagues of large universities, who I think have a special problem in this area, and believe that there aren't any solutions that would get them from where they are now to the kind of teaching that we specialize in, even at the introductory level.

I want to stress that our first recommendation that has been touched on by a number of us is really reform and reformulation of the introductory courses. That's where we lose about 40 percent of the able and well-prepared students who go to college who plan on doing something significant in science and mathematics.

We lose them there because the introductory courses tend to be large, they tend to be passive, they tend not to involve this kind of investigative learning, and they tend typically, although not exclusively, to be located in the larger universities there this is this special problem of teaching and research in competition.

Mark Wrighton said at that meeting, after a number of presidents had lamented that the inertia and difficulty and financial requirements from NSF, tens of millions of dollars would need to be poured into each institution to allow them to change this incentive structure, he said:

> I am puzzled, because each year we get something which comes to us, that we have complete freedom to decide how to spend. It's called tuition.
>
> At MIT tuition is fairly high, and as provost I get to sit down and talk with my colleagues about how to spend it. We have the freedom as an institution to change the way we prioritize our expenditures in teaching and research, and it's not easy.

He certainly recognizes the difficulty. But I think that is what it's going to take: commitment on the part of all of us to imagine that the outcomes and the structure and process could be different. I think it can. I think it's really a matter of choice and priorities within institutions, in the context of significant NSF and other leadership in the wider society.

My colleagues may have a different answer, but that's one point I would make.

Dr. Doyle. I really think the problem that we have, at least publicly,[1] about the conflict between research and teaching is virtually reversed in predominantly undergraduate institutions. A person who is a faculty member for an administration which operates a predominantly undergraduate institution does so [2] with the aspect that teaching is the first priority of all its constituencies.

In fact, research has always been and continues to be in most institutions something that is done ad hoc, beyond the normal operations of the faculty member.

Our problem at predominantly undergraduate institutions is getting the attention and support that allows that to be integrated within our course structure and within the educational experience of the students that are involved.

As a result of that, of course, those institutions that have practiced it (undergraduate research) have been very successful in promoting careers for their students in science. Those that have not, in studies that I have performed, that have not been as effective,[3] also were not as effective in actually promoting their students to careers in science.

What the National Science Foundation can do, of course, is to allow programs that are already underway and growth in [4] new programs to make it possible for faculty who are working with higher teaching loads, significantly higher teaching loads, and with more constrained resources, to undertake this research experience, to give them a chance, to put it down [5] as an experience that should happen if the ideas are good, not if the productivity is substantial.

Consequently, I think our national discussion on research versus teaching might be placed in a different context when one is referring to these institutions.

Dr. Light. You asked what is the key to the success of these institutions, and I think it can be summarized in basically one phrase, and that is that the teaching involves an apprenticeship from training which is much different from a large lecture and a canned lab. One colleague who is a scientist explained this to me by saying he made sure that his students had the opportunity to fail. Once they have failed with a hypothesis, they understand what science is. That does not happen in a big lab where the results are predetermined.

What can be done to encourage this in places where it is not taking place? What can be an incentive? That was the other part of your question. Well, as I look at the vast majority of programs which offer rewards in terms of grants, support and recognition across the country, they are targeted towards research, they are not targeted towards research plus teaching or teaching plus research. And they don't take account of, recognize or reward the people like these two gentlemen at the ends of the table who are doing this frequently, all the time, with their students.

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[1] Dr. Doyle changes his statement to read "I really think the problem to which you refer, about the conflict . . ."

[2] Dr. Doyle changes the word "so" to "research."

[3] Dr. Doyle deletes the words "that have not been as effective."

[4] Dr. Doyle deletes the words "growth in."

[5] Dr. Doyle rephrases "put it down" to "understand it."

That really is where we need some help from the Federal Government. By reward, let me say I don't mean only the grants which would go to them and give them a level playing field in which to play, although that is terribly important. I also mean such things as the facilities and equipment with which they work, because they are condemned too frequently to working with equipment which is out of date, because they can't afford more.

Those are the things I think would be most helpful.

Mr. WOLPE. Okay. Dr. Swartz?

Dr. SWARTZ. Three years ago, at a Council on Undergraduate Research meeting, the then-director of the National Science Foundation cautioned us to not try to emulate the research universities. I want this committee to understand clearly that we understand that.

The situation in the setting of the predominantly undergraduate institutions is that research is done with undergraduate students, and research brings us closer to the students, it doesn't draw us away from the undergraduate students as is the typical case at a research university.

Mr. WOLPE. So in a sense, even in terms of grant allocation by the Federal Government, greater emphasis on precisely the kinds of research that are done in conjunction with undergraduate education, where you have been doing them independently, would be helpful.

Dr. SWARTZ. Right.

Mr. WOLPE. I should say, in my own institutions, I did college and then MIT, I have had a bit of both, but in both instances as a political scientist, not as a hard scientist, as they would say.

Dr. Sullivan, in your testimony and in a letter from Project Kaleidoscope to Dr. Massey, you emphasized the need for strong oversight of the Research in Undergraduate Institutions program. What does the Research in Undergraduate Institutions program do, why is oversight of this program so important?

Dr. SULLIVAN. What it does, what it attempts to support, is precisely what these gentlemen have been talking about. When research in RUI is supported in our institutions, it is research by a faculty member which always involves students as collaborators, and it is in a sense the upper level epitome of the kind of investigative teaching that we attempt to bring into the whole curriculum.

The oversight—I would use a different word now than oversight. I think our concern is that in RUI, which is a targeted program as opposed to a budgeted program, in which one has to—a faculty member at a college like ours—has to relate to the research program director in a particular area. There are a lot of those research program directors.

And the RUI program—one of its most significant, perhaps the most significant purpose, I believe, is the support of this kind of research and education enterprise combined. It's really a question of where the emphasis is going to be and where the educational component is going to receive its leadership, support and commitment.

We believe that can happen best when it is coordinated in a single place, where institutions like ours can relate to it in a single way. And in fact, if the money were budgeted as opposed to targeted so that it is there, it is accountable, and as things change over the course of a year, it can't be reallocated to other purposes without visible discussion and review.

I know the other side of it, because I have talked to people at the assistant director level in the NSF, that the research directors are concerned, they are terribly interested in science education, they are involved in a coordinating committee effort to make sure the educational components of their programs are given appropriate attention.

But we still believe, nonetheless, that this critically important, perhaps the most central, one of the most central, kinds of support NSF provides science education would be done more effectively and in a more enabling way if it were handled in a single office.

Mr. WOLPE. So you are concerned, then, about the distribution of the program among the different research directorates?

Dr. SULLIVAN. That's right. It tends to disappear and, because it doesn't have a single focus, our concern is that it may lose visibility, as Dr. Doyle has implied, that faculty at our institutions, because it is dispursed throughout the Foundation, may not have easy enough access to it, and that financial support of the most critical kind to our institutions and to our students is then less and the things NSF really wants to do, and we think that you want to do with your money, are made less easy.

Mr. WOLPE. Dr. Doyle?

Dr. DOYLE. I would like to clarify. There is an up side and a down side to budgeting formula. When RUI was first introduced as a targeted program, it was sensed that it was a $3 million program. The first year, almost $6 million was expended on that program because it was targeted, and the research directorates actually went beyond that target. That has continued for every year up until a couple of years ago when, in fact, proposal pressure and an interest, in my perception, decreased, and now targets are not met from the sense of the division.[6]

The other problem that exists without having a coordinating activity—that in its initial years Joe Danek from the National Science Foundation that you mentioned earlier, was primarily responsible.[7] There are problems in coordination that result in reviews that one does not know what impact they have on final decisions.

For example, one of the reviews of an RUI proposal stated—two of the three reviewers of this particular proposal said that they rated this person down, decreased the rating, because that person was at a small school and that person's project was too good for the institution. Those are inappropriate comments that, one would like to have a sense, that those [8] would be actually removed from any consideration.

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[6] Dr. Doyle changes "from the sense of the division" to "in all of the Research Divisions."

[7] Dr. Doyle adds the words "for coordination" after the word "responsible."

[8] Dr. Doyle deletes the words "that those."

Other comments were made. One reviewer said to this individual, "Give no funding to it because it does not contain graduate students." Now, coordinating activity on this program would give at least the outside community a sense that such comments would be considered inapplicable and would actually be dismissed. There would be somebody actually watching that.

Mr. **WOLPE**. A clearer sense of the mission, if there was a central focus?

Dr. **DOYLE**. That's right.

Dr. **LIGHT**. A question of incentives was raised a while ago. Part of what's missing here is an incentive for a person or group within NSF to take accountability for undergraduate science teaching. That isn't really a critical mission, and that's why this kind of thing happens, that's why this kind of peer review takes place.

Mr. **NAGLE**. Let me pick up on that and ask you this. Is NSF, assuming we made the funding recommendations that are called for, is NSF ready to implement those programs, in your judgment?

Dr. **LIGHT**. I wouldn't be able to say. Earlier I gave a contrast between the Department of Education International Division and my own personal experience with NSF and related agencies and there really is a difference between the two branches of the Government in terms of a couple of individuals in the Department of Education International Division who took on as a personal matter for which they would be accountable the teaching of foreign languages. And they have made a huge difference in the past 10 years. That kind of mission sense is the kind of thing that is missing.

Mr. **NAGLE**. Let me ask the panel that question.

Dr. **SULLIVAN**. I would answer unequivocally yes. There is commitment, there is vision within the NSF area. There is a strong—and I think growing stronger—education and human resources directorate. The programs we need are largely in place, and I think these criticisms—and I would share Mike Doyle's concern about that—are really corrective to something that is essentially structured in a way which we think is beneficial.

Mr. **NAGLE**. I am loathe to give hypothetical questions to a group of scientists, because I am in over my head, but——

Dr. **SULLIVAN**. I'm a social scientist.

Mr. **NAGLE**. You're okay. [Laughter.]

You're all right. You and I can talk, okay? The rest of you, just don't listen to this.

But we are talking about an agency here where we have seen a significant lack in initiative, a decline in the budget, a decline in advocacy for budgetary outlays from 1968 to the present. It's kind of a treadmill path. I would have to say that the history of the NSF advocacy for these types of things we're talking about historically has not been there. What leads you to believe they will be there now?

Dr. **SULLIVAN**. I think it has been the Project Kaleidoscope experience itself. The NSF brought us into being, brought us together, asked us to raise these questions pretty basically. Again, I am not an apologist for the NSF, that's not my role. But I have meant to suggest that a great many of our faculty and presidents of colleges like ours feel a very sympathetic resonance with Dr. Massey's appointment, with Dr. Williams' appointment, and existing staff there. Yet there are some difficulties we are addressing that we believe need attention.

Mr. NAGLE. Pursuing that just for a second—then I want to hear everybody's comments on it—how in the world did we get into the boat we're in?

Dr. SULLIVAN. I think one just looks back to the history you were referring to, in 1981 or 1982, we zeroed out undergraduate funding, and this committee, and other members of Congress helped to get it back. But people have changed. And there are—I am suggesting that we find significant resonance and reinforcement there as well as some resistance. We think all our ideas are exactly right, of course.

Dr. DOYLE. I would like to point out to the committee that in fact, the programs that have been vital and essential to the development of that community of[9] research active environment for undergraduate students came out of the programs that were initiated through the NSF in the mid 1980s. What has not happened since that time is a review that allows a change in the direction of the program, and enhancement of the program, and redefinition that would revitalize these activities.

There are constraints within the National Science Foundation. In fact, within the first year after the introduction of these new programs the then-director of the Foundation, when a group met with him on the program, asked "How long do these programs have to exist? Isn't this something that we actually deal with on a temporary basis? Isn't this just the feeding through of something that is temporary?"

What I think the sense of[10] this committee, and certainly of Project Kaleidoscope, has had is that there is and must be an ongoing commitment to the understanding that there is a different operation here.

Mr. NAGLE. I get the feeling in talking with them about undergraduate research, and even primary and secondary educational research, that they still perceive their role as one of a stimulus. They start their project and then they move on, they start a project and move on, and there is no continuum to the programs, nor is there any review to the program for the enhancement of it. Dr. Light, you are nodding your head. Do you concur?

Dr. LIGHT. Yes, I do concur, because that has been too frequently the case. I am not in any sense in my dissent denigrating the fine work of the individuals in the agency. However, my sense is that we wouldn't be facing the difficulties in funding undergraduate science in the private sector, which as we have already demonstrated is a source of a disproportionate number of our future scientists, if in fact there was a steadier level of funding for the most expensive parts of doing science.

And that's the problem. The most expensive parts of doing science do not have a steady form of funding.

Mr. WOLPE. Carrying that further, if I may, may not the problem that has been characterized here, of the lack of sufficient focus to build upon a commitment that has been expressed in earlier years, going to be compounded by the recent decision to scatter, essentially, the RUI program among the different research directorates, rather than maintain a centralized administrative direction? Dr. Sullivan, you phrase it more delicately than I just did, but isn't that the concern you are raising?

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[9] Dr. Doyle deletes the words "community of."

[10] Dr. Doyle changes the word "of" to "that."

Dr. Sullivan. True.

Mr. Nagle. If that's the case, let me go back to my first question, which was, is NSF ready to go assuming a given funding level, when in fact the most recent history is one of scattering, as my colleague has suggested?

Dr. Sullivan. I [NSF] will have to answer later.

Dr. Swartz. I think particularly in the undergraduate office of the National Science Foundation, we have had an auspicious start. That is a relatively recently founded organization, and there are some excellent programs there. The Instruments and Laboratory Improvement program is an excellent program.

The Course and Curriculum program, which was just founded this year,[11] just reviewing its first round of proposals, is a good program. The Undergraduate Faculty Enhancement Program—those programs only affect a very small number of individuals, and the problem is bigger than that.

Mr. Nagle. Will it be sustained? Will it be reviewed? Will it be enhanced? Based on history, we would have to say no, and that's——

Dr. Doyle. No, I think that's the wrong conclusion. The driving force for programs that have been associated with the research community such as the Research in Undergraduate Institutions and the Research Experiences for Undergraduates, have been operated generally very well. The data that we have say overall one gives positive marks to the operation of this. There is dissension. There are examples of horror stories, however,[12] but they represent the exception to the general rule.

In general, the research directorates of the National Science Foundation have paid attention to these programs, have supported these programs. What is lacking from them oftentimes is that oversight that does not allow the exceptions to exist with the frequency they are beginning to exist.

Mr. Wolpe. With that, I am going to ask that we recess at that point, so that Mr. Nagle and I may cast our votes. We will return shortly.

[Recess.]

Mr. Wolpe. The hearing will resume at this point. Mr. Nagle, I believe you have a question.

Mr. Nagle. Dr. Swartz, one thing that kind of perked my interest in your written statement, you indicate that the establishment of the right type of curricular development programs will be critical to their success. I wonder if you would amplify on that, exactly what you mean.

Dr. Swartz. Yes, I would like to make a few comments there. Really what I am going to do is amplify a comment that President Sullivan made earlier. I think the style of curricular innovation or reform programs that NSF establishes will be critical to their success. As the NSF expands its programs which attempt to reform science curricula, the design of those programs will be critical.

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[11] Dr. Swartz adds the words "and is" just . . . .

[12] Dr. Doyle deletes the word "however."

It is often tempting to single out a few select, highly visible institutions, fund them at high levels, and expect them to devise excellent curricula that everyone would adopt. To do that would be to repeat the mistakes of centrally planned economies. That is to say, that you have such good ideas that all should adopt them.

The problems here are manifest. First, it assumes that there are several curricular models which will work everywhere. There is absolutely no evidence that that is the case. Faculty do their best teaching and students do their best learning when they have invested themselves. Just as in economic development, the most successful work comes out of an entrepreneurial spirit, when many individuals have an opportunity to try their own ideas.

Some of those ideas will be outstanding, noticed by others and emulated. But the key to excellence is to promote individual efforts. If we adopt the centrally planned economy approach, we doom ourselves to the degree of success which we now see results from that approach.

So what we need to be doing is funding a large number of small projects, rather than focusing in on a very few very large projects.

Mr. NAGLE. You want the diversity, in other words?

Dr. SWARTZ. I think it is absolutely essential, diversity and stimulating the entrepreneurial spirit.

Mr. NAGLE. I was supposed to say nice things about you Jim, but your testimony speaks for itself. I forgive the fact that you are not a social scientist. But you do an outstanding job at Grinnell College, and you are a source of advice and counsel for me.

I reviewed carefully your statement before I came this morning, and obviously you are well prepared, as were the rest of the panel. It is a pleasure to welcome a constituent to the committee, and I thank you for your insight and observations.

Dr. SWARTZ. Thank you.

Mr. WOLPE. Thank you very much, Congressman Nagle. I have one last question. Dr. Swartz, you stated in your testimony that the Instrumentation and Laboratory Improvement program with the NSF has a requirement for 50 percent matching funds, that is, money the school must provide from non-Federal sources. You recommended this requirement be decreased to 35 percent. Do you think this would allow more schools to participate who are now unable to provide the 50 percent matching funds? What impact do you believe that change would have?

Dr. SWARTZ. We have a situation now where many of our institutions, similar to my own, even the most wealthy institutions, are in fact rationing the number of proposals that can be submitted from the institution, because of this required 50 percent match. Institutions do not feel they have the resources to provide matching funds.

The problem this generates is that the National Science Foundation is then not necessarily seeing the best ideas. They are only seeing a preselection of ideas. If we could decrease the matching requirements—and this problem is particularly acute in less wealthy institutions, for instance, the historically black colleges and universities.[13]

So I think if we could decrease the matching fund requirements somewhat in the program, that would attract a broader array of proposals and allow the peer review process of the National Science Foundation to really select the best programs for funding.

Mr. **Wolpe**. Great. I want to join in Congressman Nagle's expression of appreciation to all of you for some truly excellent testimony, both written and verbal. We hope that some of what you have to offer, and the Project Kaleidoscope recommendations, will be heeded by NSF and they will be able to move forward more aggressively and with greater focus in the weeks and months ahead.

Thank you all very much.

[Inserts of Luther College and Loras College follow:]

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[13] Dr. Swartz adds the words "that would be an improvement."

Luther College

JUL [illegible] 1991

July 8, 1991

Representative Dave Nagle
Third District Iowa
214 Cannon House Office Building
Washington, D.C. 20515

Dear Representative Nagle:

I understand that the House Subcommittee on Investigations and Oversight is conducting a hearing on "Traditional and Non-traditional Sources of Future Research Scientists." You are well aware of the role that small liberal arts colleges play in training scientists, including the fact that we graduate science majors at a much higher level than the national average and our students earn Ph.D.s more consistently than do graduates of any other kind of institution.

In order to allow small liberal arts colleges to continue to produce future scientists, several things are necessary. First, strong well-prepared science faculty must be employed. Support from NSF for start-up costs for new faculty positions, support for research programs, and support for laboratories and equipment are ways that federal dollars can augment the resources of small liberal arts schools. Second, because attending small liberal arts colleges can be more costly to families than attendance at state schools or junior colleges, continuing a strong program of federal grants and loans for capable students who wish to attend liberal arts schools will continue to support students who wish to pursue careers in science.

I appreciate your support for science education and we will be pleased to respond if there are other ways we can serve you.

Sincerely,

Jane Jakoubek

Jane Jakoubek
Associate Dean of the College

JJ:jg

DEAN OF THE COLLEGE
LUTHER COLLEGE DECORAH, IOWA 52101-1045 /319/387-1005

LORAS COLLEGE

DEPARTMENT OF CHEMISTRY 1450 ALTA VISTA DUBUQUE, IOWA 52004-0178

JUL 10 1991

July 4, 1991

Dear Representative Nagle,

Here are my thoughts on "Traditional and Nontraditional Sources of Future Research Scientists" for the House Subcommittee on Investigations and Oversight. I am pleased and honored to contribute.

Our experience at Loras College shows that two NSF programs have had significant positive effects on the training of future research scientists. These are the REU program and the Research Opportunity Award Program.

We have had several students participate in REU programs at liberal arts colleges and at larger research oriented universities. These experiences have been very good ones for the students and have encouraged them to consider research careers more realistically and more favorably. These students have communicated their enthusiasm to their peers upon their return to Loras and this has stimulated interest in research in all our chemistry students. I would also mention the DOE program for research at Argonne National Lab and other DOE labs which has had similar positive effects on Loras students. I strongly encourage continued support of this program.

We have placed both sophomores and juniors in REU programs with success. I believe it will be difficult, in chemistry at least, to create valid independent research summer programs for freshman level students. Independent research can be very frustrating for a student who is still learning basic laboratory technique, and this frustration can discourage those we hope to encourage. Perhaps a more structured program can be created for college freshman and upper level high school students that still exposes them to the excitement of research.

Dr. Joe Schaefer (physics and engineering) and I received NSF Research Opportunity Awards to conduct research at the University of Iowa and at the University of Wisconsin during the summers. In both cases the awards have led to continuing research collaborations, and revitalized research efforts here at Loras. In addition the opportunity to do state-of-the-art research has improved our ability to teach modern techniques and helps us serve as better role models to our students, and our colleagues. A third faculty member, Dr. Carl Binz (chemistry) has received a similar award through the Argonne National Lab. Both the NSF ROA program and the Argonne program have had a very big impact at Loras and deserve continued support.

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The revitalized research at Loras requires continuing support so that undergraduates can participate directly. This is the role of the NSF RUI program. Unfortunately we have no direct experience with this program but I encourage its continued support. The U.S. needs a program that increases the contribution undergraduate colleges makein training future scientists. The program must also understand the time and manpower difficulties that we who conduct research with undergraduates face, and the minimal support we can expect from college administrations unfamiliar with the federal granting agencies. The Research Corporation is a good model for a program in this area. Brian Andreen and the Research Corporation board understand the problems we face and do an excellent job supporting undergraduate research. Some of the funds the Research Corporation distribute come from private corporations. I encourage the Congress to maintain and to increase the incentives for private corporations to support research at undergraduate institutions either directly or through organizations like Research Corporation.

Training future research scientists requires more money for equipment and laboratory supplies than many other academic research projects. Research with undergraduates requires significant amounts of faculty time. These factors combine to make it difficult for private colleges to maintain high quality programs and reasonable tuition. We need help through instrumentation grant programs and direct student assistance. The NSF already has instrumentation programs which need continued support. NSF and various private organizations have direct support for graduate students who choose science careers. I believe we need direct support at the undergraduate level for students who choose to study to become research scientists. This program could incorporate incentives for women and minorities, as the NSF graduate programs do. The increased cost of high quality programs at small colleges has traditionally been offset by private donations. Congress must continue and enhance the incentives for individuals and corporations to support education.

If I can be of any further assistance please contact me.

Sincerely,

David Speckhard

Dr. David Speckhard
Professor and Chairman of Chemistry

Mr. **Wolpe**. I would like to now invite our second panel of witnesses to come forward. In our second panel, we will be looking at nontraditional sources of science students, those groups that are underrepresented in science. We will hear about the Project Kaleidoscope findings and recommendations on this subject. We also want to learn about how to encourage and enable more African-Americans, Hispanics, Native Americans and women to pursue science at the undergraduate level.

We would like to find out how certain schools, such as the historically Black universities and women's colleges, are able to be so effective in graduating such a high percentage of outstanding women and minority students in science.

For example, 40 percent of African-Americans who receive baccalaureate degrees in science earn their degrees at historically Black universities and colleges. And as we did in the previous panel, we want to examine ways in which the approach of the successful schools and programs can be adopted at other institutions.

Our first witness will be Dr. Thomas Cole, President of Clark Atlanta University in Atlanta, Georgia. Dr. Cole served as a member of the Project Kaleidoscope executive committee. He will be followed by Dr. Gerald Stokes, who is a Professor of Microbiology at George Washington University. He will be speaking to us today as the Chairman of the Committee on the Status of Minority Microbiologists of the American Society of Microbiology.

Next will be Dr. Maggie O'Brien, a biochemist who has very recently begun her tenure as President of Hollins College, a women's college in Roanoke, Virginia. Our final witness on the second panel is Dr. James Gentile, Dean of Natural Sciences and Professor of Biology, at Hope College in Holland, Michigan. Dr. Gentile also served on the Project Kaleidoscope executive committee.

I would like to first ask if any of our witnesses object to being sworn in. If not, would you all please stand.

[Witnesses sworn.]

Mr. **Wolpe**. I would also like to remind the witnesses of our five-minute time constraint. Of course, your written testimony will be entered into the record in its entirety. I should also indicate that in a few minutes I will be called away for a short period of time and Congressman Nagle will be assuming the chair, so we will continue without interruption.

With that, let me invite our first witness on this panel, Dr. Thomas Cole.

TESTIMONY OF THOMAS COLE, JR., PH.D., PRESIDENT, CLARK ATLANTA UNIVERSITY, ATLANTA, GA

Dr. **Cole**. Thank you very much, Mr. Chairman, for the opportunity to appear before this subcommittee. I appear after having spent 25 years as a research chemist, a member of the faculty of an historically Black college and University and the faculty of a major research university. I am now President of Clark Atlanta University.

Clark Atlanta is a new, comprehensive, historically Black university created three years ago from the consolidation of Clark College and Atlanta University, each of which was more than 120 years old. We are now one of only two historically Black private comprehensive universities in the country, offering a program from the freshman year to the doctorate.

In your opening remarks, you set the tone which was included in my introductory remarks, and I won't repeat that, except to say that when you talk about the deficits in science and engineering education, for minorities and women, the numbers are much worse. The Project Kaleidoscope report to which you refer, along with many other studies, makes the point very clear.

Women and minorities can succeed in great numbers in science and mathematics. This success is greatest in settings in which the environments or caring and nurturing that provide research opportunities in close collaboration with faculty who are concerned that students succeed.

The data are clear in this regard at private liberal arts college, both coeducational and single sex. These institutions have been especially productive in educating a higher percentage of women science graduates than any other non-specialized category of institutions. The record of historically Black colleges and universities, as you indicated, in the education of African-American scientists, have been especially impressive.

In the mathematical and physical sciences, 45 percent of the 1987-1988 bachelor's degrees that were awarded to African-Americans were earned by graduates at HBCUs where less than 20 percent of Black undergraduates are enrolled. A number of historically Black colleges and universities are among the most productive of all institutions in the percentage of their graduates with degrees who go on to receive Ph.D. degrees in the sciences and mathematics.

And a greater proportion of Hispanic graduates receive their undergraduate education in Puerto Rican colleges and universities and predominantly Hispanic institutions in the Southwest and other regions of the country with large Hispanic populations.

The tragedy, Mr. Chairman and members of the committee, is the non-participation of the vast majority of America's colleges and universities in the preparation of minority science and mathematics majors.

Nearly all U.S. colleges and universities have African-American and Hispanic students, but in 1986 and 1987, fewer than 100 colleges had more than two Blacks mathematics baccalaureate graduates. Fewer than 90 had more than two Black graduates. Only 33 had more than two Hispanic mathematics graduates. Only 49 had more than two Hispanic physical science graduates. And only 133 had more than two Hispanic life science graduates.

In 1988 and 1989 the U.S. Office of Education reports that of the 154,000 baccalaureate degrees awarded in the science and engineering fields by all American colleges and universities, just over 11,000, or 7 percent, were received by African-Americans, Hispanics and other minorities. If it were not for historically Black colleges and universities and predominantly minority institutions, the figures would be far worse.

At the doctorate level, the statistics are even more disturbing. In 1988 and 1989, there were 12,800 Ph.D.s awarded in the natural sciences and engineering. African-Americans earned 128. Hispanics earned 151. For African-Americans, this represented a decrease, both in absolute numbers as well as percentage from the statistics of 10 years earlier.

The point I want to make in citing these statistics is to suggest to you that this performance by America's colleges and universities is nothing short of a national disgrace. That is one of the factors that motivated the trustees of Atlanta University and Clark College three years ago to create Clark Atlanta University as a comprehensive, private university, to fill a void in American higher education, to give African-Americans another option to pursue their bachelors, masters and doctorate degrees.

It has been demonstrated rather dramatically at many of the Nation's liberal arts colleges and at the institutions to which I refer that these are institutions with proven track records of success. A major part of the solution to the problem of the underrepresentation of women and minorities can be solved if we put the resources at institutions that will yield the largest return on the investment.

I am pleased to tell you that the National Science Foundation and other Federal agencies are increasingly recognizing this as an important strategy. There are programs at NSF, for example, that focus on HBCUs, and on minority institutions, and on increasing the representation of women and minorities and persons with disabilities in science. But the budgets for these programs are modest in comparison with the overall science, mathematics and engineering budgets, and they should be increased substantially if they are to make the dramatic, numerical impact that is needed.

We have to put the resources where the students are, Mr. Chairman, and at those institutions that have a demonstrated track record in the production of minority and women scientists. That means at the Nation's liberal arts colleges and women's colleges and historically Black colleges and universities and predominantly minority institutions. And I would add to this list certain community and junior colleges which have disproportionately large enrollment of minorities.

I would suggest further that current programs at the National Science Foundation are fundamentally sound and can accomplish this objective, but they need increased funding if we are to realize the numerical goals that have been set for the year 2000.

We know what works, and we know the magnitude of the challenge. We think the program elements are already in place. What we need is increased support for those programs that can be targeted at those institutions that will have a historical commitment and track record that can produce the desired results.

Thank you very much.

[The prepared statement of Dr. Cole follows:]

TESTIMONY BEFORE THE

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES
ROOM 2325 RAYBURN HOUSE OFFICE BUILDING

"TRADITIONAL AND NONTRADITIONAL SOURCES OF FUTURE RESEARCH SCIENTISTS"

THOMAS W. COLE, JR., PH.D.
PRESIDENT, CLARK ATLANTA UNIVERSITY
ATLANTA, GEORGIA

JULY 11, 1991

"UNDERGRADUATE SCIENCE EDUCATION: TRADITIONAL AND NONTRADITIONAL SOURCES OF FUTURE RESEARCH SCIENTISTS"

THOMAS W. COLE, JR.
PRESIDENT, CLARK ATLANTA UNIVERSITY

THANK YOU, MR. CHAIRMAN, FOR THIS OPPORTUNITY TO APPEAR BEFORE THIS SUBCOMMITTEE TO PRESENT TESTIMONY ON UNDERGRADUATE SCIENCE EDUCATION. MY NAME IS THOMAS COLE, AND I AM PRESIDENT OF CLARK ATLANTA UNIVERSITY IN ATLANTA, GEORGIA. CLARK ATLANTA IS A NEW, COMPREHENSIVE, HISTORICALLY BLACK UNIVERSITY, CREATED THREE YEARS AGO BY THE CONSOLIDATION OF ATLANTA UNIVERSITY AND CLARK COLLEGE, EACH OF WHICH WAS MORE THAN 120 YEARS OLD. WE ARE ONE OF ONLY TWO HISTORICALLY BLACK PRIVATE COMPREHENSIVE UNIVERSITIES IN THIS COUNTRY OFFERING PROGRAMS FROM THE FRESHMAN YEAR TO THE DOCTORATE. WE ARE PART OF A CONSORTIUM OF SIX HISTORICALLY BLACK INSTITUTIONS THAT INCLUDES MOREHOUSE, MORRIS BROWN AND SPELMAN COLLEGES, THE INTERDENOMINATIONAL THEOLOGICAL CENTER AND THE MOREHOUSE SCHOOL OF MEDICINE. COLLECTIVELY, THESE INSTITUTIONS ARE KNOWN AS THE ATLANTA UNIVERSITY CENTER, THE LARGEST CONSORTIUM OF BLACK PRIVATE HIGHER EDUCATION IN THE WORLD, WITH MORE THAN 9,000 STUDENTS AND 600 FACULTY.

TODAY, YOU WILL HEARING TESTIMONY FROM SEVERAL WITNESSES ON THE STATE OF UNDERGRADUATE SCIENCE EDUCATION IN THE UNITED STATES. I WANT TO FOCUS MY REMARKS ON THE FINDINGS AND RECOMMENDATIONS OF THE PROJECT KALEIDOSCOPE REPORT RELATED TO THE RECRUITMENT AND RETENTION OF WOMEN AND MINORITIES IN UNDERGRADUATE SCIENCE PROGRAMS.

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE, YOU ARE ALL VERY FAMILIAR WITH THE MANY

REPORTS AND STUDIES OF THE LAST SEVERAL YEARS THAT LAMENT THE DEFICIENCIES OF OUR EDUCATION SYSTEM, FROM KINDERGARTEN TO GRADUATE SCHOOL, PARTICULARLY WITH REGARDS TO THE PRODUCTION OF SCIENTISTS AND ENGINEERS. THE NATIONAL SCIENCE FOUNDATION HAS ESTIMATED THAT BY THE YEAR 2010, OUR NATION WILL BE SHORT BY MORE THAN 600,000 SCIENTISTS AND ENGINEERS.

THE CURRENT AND PROJECTED ACUTE SHORTAGES IN OUR TRAINED TECHNICAL WORKFORCE AFFECT THE MORE SKILLED TECHNICAL AND SCIENTIFIC SEGMENTS OF OUR BUSINESS AND INDUSTRY, AND THE EDUCATIONAL ESTABLISHMENT ITSELF AS WE STRUGGLE TO FIND ADEQUATE NUMBERS OF FACULTY AND TEACHERS, IN THE SCIENCES AND ENGINEERING. THE TASK FORCE ON WOMEN, MINORITIES AND THE HANDICAPPED (ESTABLISHED BY PUBLIC LAW 99-383, SECTION 8) STATED IN ITS REPORT THAT "...ONE OF OUR MOST URGENT TASKS IS TO STRENGTHEN OUR SCIENCE AND ENGINEERING WORKFORCE. THE EDUCATION PIPELINE -- FROM KINDERGARTEN THROUGH THE PH.D. -- IS FAILING TO PRODUCE THE WORKERS NEEDED TO MEET FUTURE DEMAND."

THE TASK FORCE REPORT ALSO STATED THAT BY THE YEAR 2000, 85 PERCENT OF NEW ENTRANTS INTO THE NATION'S WORKFORCE WILL BE MINORITIES AND WOMEN; YET, THESE ARE THE GROUPS THAT HAVE TRADITIONALLY BEEN UNDERREPRESENTED IN THE SCIENCE AND ENGINEERING PROFESSIONS. WITH THE IMPENDING RETIREMENT OF POST WORLD WAR TWO BABIES, WE ARE IN GRAVE DANGER OF NOT PRODUCING ENOUGH SCIENTISTS AND ENGINEERS TO MEET THE NATION'S WORKFORCE REQUIREMENTS UNLESS WE ACT NOW! ALONGSIDE THE WAR ON DRUGS, WE NEED TO LAUNCH A SIMILAR MOBILIZATION TO IMPROVE EDUCATION AT ALL LEVELS, TO ACHIEVE ALL SIX OF THE NATIONAL EDUCATION GOALS, THREE OF WHICH ARE RELATED DIRECTLY TO MATHEMATICS AND SCIENCE EDUCATION, AND PRODUCE THE TRAINED TECHNICAL WORKFORCE TO MEET THE FUTURE TECHNOLOGICAL NEEDS OF THE COUNTRY.

WE MUST LOOK AT THE ENTIRE EDUCATIONAL PIPELINE IF WE ARE TO BE SUCCESSFUL IN DESIGNING AND IMPLEMENTING STRATEGIES WHICH WILL BOTH RESTORE AMERICAN COMPETITIVENESS IN THE SCIENCES AND ENGINEERING AND PROVIDE REASONABLE OPPORTUNITIES FOR MINORITIES AND WOMEN TO CONTRIBUTE TO THIS NATION'S TECHNICAL WORKFORCE. THERE ARE MANY FACTORS THAT CONTRIBUTE TO THE UNACCEPTABLY LOW NUMBER OF MINORITIES AND WOMEN IN SCIENCE AND ENGINEERING WORKFORCE THAT ARE BASED ON CRITICAL EDUCATIONAL HURDLES IN GRADE SCHOOL, HIGH SCHOOL AND IN BACCALAUREATE WORK

LEADING TO THE TERMINAL DEGREE IN THESE FIELDS."

A SIGNIFICANT PART OF THE SOLUTION CAN BE FOUND BY FOCUSING ON UNDERGRADUATE EDUCATION AND UTILISING AS MODELS THE EXAMPLES OF THOSE INSTITUTIONS THAT HAVE HISTORICALLY BEEN SUCCESSFUL IN PRODUCING MINORITY AND WOMEN SCIENTISTS AND ENGINEERS AS DOCUMENTED IN THE PROJECT KALEIDOSCOPE REPORT.

THE PEAL REPORT ALONG WITH MANY OTHER STUDIES MAKE THE POINT CLEARLY: WOMEN AND MINORITIES CAN SUCCEED IN GREAT NUMBERS IN SCIENCE AND MATHEMATICS, AND THIS SUCCESS IS GREATEST IN SETTINGS -- BOTH SINGLE SEX AND COEDUCATIONAL -- CHARACTERISED BY LEARNING COMMUNITIES -- ENVIRONMENTS THAT ARE CARING AND NURTURING AND THAT HELP STUDENTS SUCCEED.

THE DATA ARE CLEAR IN THIS REGARD. PRIVATE LIBERAL ARTS COLLEGES -- BOTH COEDUCATIONAL AND WOMEN'S COLLEGES -- HAVE BEEN ESPECIALLY PRODUCTIVE, EDUCATING A HIGHER PERCENTAGE OF WOMEN SCIENCE GRADUATES THAN ANY OTHER NON-SPECIALISED CATEGORY OF INSTITUTION. AND, THE RECORD OF HISTORICALLY BLACK COLLEGES AND UNIVERSITIES (HBCU'S) IN THE EDUCATION OF AFRICAN AMERICAN SCIENTISTS HAS BEEN ESPECIALLY IMPRESSIVE.

IN THE MATHEMATICAL AND PHYSICAL SCIENCES, FORTY-FIVE PERCENT OF THE 1987-88 BACHELOR'S DEGREES THAT WERE AWARDED TO AFRICAN AMERICANS WERE EARNED BY GRADUATES OF HBCU'S, ALTHOUGH LESS THAN TWENTY PERCENT OF BLACK UNDERGRADUATES ARE ENROLLED AT HBCU'S. AND, A NUMBER OF HBCU'S ARE AMONG THE MOST PRODUCTIVE OF ALL INSTITUTIONS IN THE PERCENTAGES OF THEIR GRADUATES WITH DEGREES IN SCIENCE AND MATHEMATICS AND WHO GO ON TO RECEIVE PH.D'S.

AND, THE GREAT PROPORTION OF HISPANIC GRADUATES RECEIVE THEIR UNDERGRADUATE EDUCATION IN PUERTO RICAN COLLEGES AND UNIVERSITIES AND PREDOMINANTLY HISPANIC INSTITUTIONS IN THE SOUTHWEST AND OTHER REGIONS OF THE COUNTRY WITH LARGE HISPANIC POPULATIONS.

THE TRAGEDY, MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE, IS THE NON-PARTICIPATION OF THE VAST MAJORITY OF AMERICA'S COLLEGES AND UNIVERSITIES IN THE PREPARATION OF MINORITY SCIENCE AND MATHEMATICS MAJORS. NEARLY ALL U.S. COLLEGES AND UNIVERSITIES HAVE AFRICAN AMERICAN AND

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HISPANIC STUDENTS. HOWEVER, IN 1986-87, FEWER THAN 100 COLLEGES HAD MORE THAN TWO BLACK MATHEMATICS BACCALAUREATE GRADUATES; FEWER THE 90 HAD MORE THAN TWO BLACK GRADUATES. ONLY 33 HAD MORE THAN TWO HISPANIC MATHEMATICS GRADUATES; ONLY 49 HAD MORE THAN TWO HISPANIC PHYSICAL SCIENCE GRADUATES; AND ONLY 133 HAD MORE THAN TWO HISPANIC LIFE SCIENCE GRADUATES.

IN 1988-89, THE U.S. OFFICE OF EDUCATION REPORTS THAT OF THE 154,000 BACCALAUREATE DEGREES AWARDED BY ALL AMERICAN COLLEGES AND UNIVERSITIES, JUST OVER 11,000 (7 PERCENT) WERE RECEIVED BY AFRICAN AMERICANS, HISPANICS AND OTHER MINORITIES. IF IT WERE NOT FOR HBCU'S AND PREDOMINANTLY MINORITY INSTITUTIONS, THE FIGURES WOULD BE FAR WORSE.

AT THE DOCTORATE LEVEL, THE STATISTICS ARE EVEN MORE DISTURBING. IN 1988-89, THERE WERE 13,800 PH.D'S AWARDED IN THE NATURAL SCIENCES AND ENGINEERING. AFRICAN AMERICANS EARNED 128; HISPANICS 151. FOR AFRICAN AMERICANS, THIS REPRESENTED A DECREASE IN BOTH ABSOLUTE NUMBERS AS WELL AS PERCENTAGES FROM THE STATISTICS OF 1978-89.

THIS PERFORMANCE BY AMERICA'S COLLEGES AND UNIVERSITIES IS NOTHING SHORT OF A NATIONAL DISGRACE.

IT HAS BEEN DEMONSTRATED RATHER DRAMATICALLY AT MANY OF THE NATION'S LIBERAL ARTS COLLEGES, AT PREDOMINANTLY MINORITY INSTITUTIONS, AND AT HISTORICALLY BLACK COLLEGES AND UNIVERSITIES THAT WOMEN AND MINORITIES CAN SUCCEED IN SCIENCE AND MATHEMATICS. AND SINCE THESE ARE THE INSTITUTIONS WITH THE PROVEN TRACK RECORD FOR SUCCESS, A MAJOR PART OF THE SOLUTION TO THE PROBLEM OF THE UNDERREPRESENTATION OF WOMEN AND MINORITIES WOULD BE TO PUT THE RESOURCES AT THESE INSTITUTIONS, WHERE THEY WILL YIELD THE LARGEST RETURN ON INVESTMENT.

THE NATIONAL SCIENCE FOUNDATION AND SEVERAL OTHER FEDERAL AGENCIES ARE INCREASINGLY RECOGNISING THIS AS AN IMPORTANT STRATEGY. THERE ARE PROGRAMS AT NSF, FOR EXAMPLE, THAT FOCUS ON HBCU'S, MINORITY INSTITUTIONS AND ON INCREASING THE REPRESENTATION OF WOMEN, MINORITIES AND PERSONS WITH DISABILITIES IN SCIENCE. HOWEVER, THE BUDGETS FOR THESE PROGRAMS ARE MODESTY IN COMPARISON WITH THE OVERALL SCIENCE, MATHEMATICS AND ENGINEERING BUDGETS AND SHOULD BE INCREASED SUBSTANTIALLY IF THEY ARE TO MAKE THE DRAMATIC, NUMERICAL IMPACT THAT IS

NEEDED.

AS A PRACTICING RESEARCH SCIENTIST FOR SIXTEEN YEARS, I WOULD BE AMONG THE LAST TO SUGGEST THAT INCREASES FOR THE EDUCATION AND HUMAN RESOURCES DIRECTORATE BE MADE AT THE EXPENSE OF THE RESEARCH DIRECTORATES. THE RESEARCH SUPPORT THROUGH THE GRANT MAKING PROCESS AT THE NATIONAL SCIENCE FOUNDATION AND OTHER FEDERAL AGENCIES IS ONE OF THE MAJOR REASONS THAT GRADUATE EDUCATION IN THE UNITED STATES IS THE BEST IN THE WORLD. BUT, OUR UNDERGRADUATE EDUCATION SYSTEM IS IN DANGER OF BECOMING SECOND-RATE.

WE HAVE TO CLOSE THE GAP THAT STARTED WITH THE EROSION OF SUPPORT FOR SCIENCE AND MATHEMATICS EDUCATION IN THE 70'S THAT LED TO A VIRTUAL ZEROING OF THE SCIENCE EDUCATION BUDGET IN THE EARLY 80'S. THAT FEDERAL POLICY HAS SERIOUSLY HURT THE QUALITY OF UNDERGRADUATE EDUCATION IN THE SCIENCES IN THIS COUNTRY AND , THUS, THE PRODUCTION OF THE NECESSARY WORKFORCE FOR THE 21ST CENTURY HAS BEEN SERIOUSLY COMPROMISED.

THE INCREASE IN THE FY'92 BUDGET FOR THE EDUCATION AND HUMAN RESOURCES DIRECTORATE OF THE NSF IS ENCOURAGING, BUT IF WE ARE SERIOUS ABOUT INCREASING THE NUMBERS OF MINORITIES AND WOMEN IN SCIENCE AND MATHEMATICS AS PART OF THE STRATEGY TO RESPOND TO THE PROJECTED SHORTAGES OF TRAINED SCIENTISTS AND ENGINEERS, WE HAVE TO DO MUCH MORE.

WE HAVE TO PUT THE RESOURCES WHERE THE STUDENTS ARE AND AT THOSE INSTITUTIONS THAT HAVE A DEMONSTRATED TRACK RECORD IN THE PRODUCTION OF MINORITY AND WOMEN SCIENTISTS -- AND THAT MEANS AT THE NATION'S LIBERAL ARTS COLLEGES, WOMEN'S COLLEGES, HISTORICALLY BLACK COLLEGES AND UNIVERSITIES AND PREDOMINANTLY MINORITY INSTITUTIONS. I WOULD ADD TO THIS LIST COMMUNITY AND JUNIOR COLLEGES WHICH HAVE DISPROPORTIONATELY LARGE ENROLLMENTS OF MINORITIES.

THIS DOES NOT MEAN THAT OTHER INSTITUTIONS OF HIGHER EDUCATION SHOULD BE LET OFF THE HOOK. FOR A VARIETY OF REASONS, THE EDUCATION OF MINORITY AMERICANS HAS NOT BEEN ONE OF THEIR PRIORITIES AND IN MOST INSTANCES, BASED ON PRESENT TRENDS, IT IS NOT LIKELY TO BE A PRIORITY IN THE NEAR FUTURE. WE SHOULD CONTINUE TO PUSH THEM TO DO THEIR SHARE IN THE RECRUITMENT, RETENTION AND EVENTUAL GRADUATION OF MINORITY AND WOMEN SCIENTISTS. IN THE NEAR

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TERM, HOWEVER, WE SHOULD CONCENTRATE INCREASED EFFORTS AND RESOURCES ON THOSE MODELS AND PROGRAMS THAT WORK -- AT THOSE INSTITUTIONS THAT PROVIDE A CARING ENVIRONMENT, COMMITTED MENTORS AND ROLE MODELS AND THE KINDS OF UNDERGRADUATE RESEARCH EXPERIENCES THAT BREED SUCCESS AND LEAD TO THE PRODUCTION OF GRADUATES WHO BECOME PRODUCTIVE PARTICIPANTS IN THE SCIENTIFIC ENTERPRISE OF THIS NATION, INCLUDING ENTRY INTO FACULTY POSITIONS AT OUR COLLEGES AND UNIVERSITIES.

I WOULD SUGGEST FURTHER THAT CURRENT PROGRAMS AT THE NATIONAL SCIENCE FOUNDATION ARE FUNDAMENTALLY SOUND AND CAN ACCOMPLISH THIS OBJECTIVE. THEY ALL NEED INCREASED FUNDING IF WE ARE TO REALIZE THE NUMERICAL GOALS THAT HAVE BEEN SET FOR THE YEAR 2000. AND WE SHOULD ENCOURAGE THOSE PROGRAM INITIATIVES THAT FOSTER CREATIVE PARTNERSHIPS AMONG THOSE INSTITUTIONS ACROSS THE COUNTRY THAT FOCUS ON MINORITIES IN SCIENCE -- BETWEEN COMMUNITY COLLEGES AND HBCU'S, BETWEEN HBCU'S AND THOSE PREDOMINANTLY WHITE LIBERAL ARTS COLLEGES THAT PROVIDE THE KIND OFF LEARNING COMMUNITIES CALLED FOR IN THE PKAL REPORT AND THE QUALITY EDUCATION FOR MINORITIES REPORT.

WE KNOW WHAT WORKS, MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE, AND WE KNOW THE MAGNITUDE OF THE CHALLENGE. THE PROGRAM ELEMENTS ARE ALREADY IN PLACE AT THE NATIONAL SCIENCE FOUNDATION. WHAT WE NEED IS YOUR SUPPORT FOR INCREASED FINANCIAL RESOURCES THAT CAN BE TARGETED AT THOSE INSTITUTIONS THAT HAVE THE HISTORICAL COMMITMENT AND TRACK RECORD THAT WILL PRODUCE THE DESIRED RESULTS.

THANK YOU VERY MUCH.

Mr. Wolpe. Thank you very much, Dr. Cole.
Dr. Stokes?

TESTIMONY OF GERALD V. STOKES, PH.D., ASSOCIATE PROFESSOR OF MICROBIOLOGY, GEORGE WASHINGTON UNIVERSITY SCHOOL OF MEDICINE, WASHINGTON, DC; CHAIRMAN, COMMITTEE ON THE STATUS OF MINORITY MICROBIOLOGISTS OF THE PUBLIC AND SCIENTIFIC AFFAIRS BOARD, AMERICAN SOCIETY FOR MICROBIOLOGY

Dr. Stokes. Mr. Chairman and members of the subcommittee, my name is Gerald Stokes and I am Chairman of the Committee on the Status of Minority Microbiologists of the Public and Scientific Affairs Board of the American Society for Microbiology, and the ASM representative to the National Life Science Education Summit. I am also an Associate Professor of Microbiology at the George Washington University Medical Center.

The American Society for Microbiology is the largest life science society in the world, with a membership exceeding 38,000. A major goal of ASM's strategic plan has been to develop ways to identify, attract and provide better opportunities for underrepresented groups to achieve their full potential in the microbiological sciences. This work was achieved through initiatives of the ASM's boards and committees and through collaborative efforts, which include many other life science organizations.

The Project Kaleidoscope Report and that of the National Life Science Education Summit both point out the importance of recruiting and retaining underrepresented minorities in science at the undergraduate level, and as you well know, there are many programs in place that are striving to accomplish this task.

ASM, for example, played a major role in the leadership of the organization and sponsorship of the National Life Science Education Summit, or the Wingspread Conference, which was held in Racine, Wisconsin in February of this year. This event, the first of its kind, was initiated by the ASM and attracted representatives from 30 life science organizations, which has a combined membership of nearly half a million scientists and science educators.

The report from the National Life Science Education Summit supports many of the recommendations of the Project Kaleidoscope report, particularly its emphasis on strengthening undergraduate science and math education. The summit report goes even further in calling attention to the need to improve precollege science education and to encourage underrepresented groups to pursue careers in life sciences.

The full report of the Life Science Education Summit has been submitted for your review. In addition, copies are available in the Office of Education and Training at the American Society for Microbiology.

Another example of the ASM's efforts is the Minority Student Science Careers Support Program, or MSSCSP. This encourages underrepresented minority students who are interested in science to pursue careers in the biological research area. The program has four components: a visiting scientist program, a summer research fellowship program, travel awards to ASM Annual Meetings, and a biological factual exchange component, which is a national clearinghouse of information on financial and training programs for students in the sciences.

This program is funded by the National Institute of General Medical Sciences through its Minority Access to Research Careers program.

The MSSCSP program of ASM has been quite successful in working with accomplished students on an individual basis. As we all know, by the time a student has chosen to continue his or her education and goes beyond high school, he or she may not be adequately prepared to pursue an undergraduate science degree. The specific skills needed to do science and to do it well are developed at a young age.

In addition, many undergraduate students have already made the decision for or against a science career at that time. To recruit students in science, particularly underrepresented minority students, emphasis must be placed on better preparation at the earliest possible level.

In recommending changes in Federal programs, particularly those of the National Science Foundation, the life science community, based on the results of the Life Science Education Summit, recommends a revised academic award program that recognizes teaching and community outreach services to be as important as research. Teaching and community outreach should be rewarded equally.

Another role for the National Science Foundation should be to serve as a catalyst for interaction and cooperation of teachers, school administrators, and scientists in efforts initiated by professional life sciences organizations. Very few programs, especially those requiring the participation of teachers, can have any success without the cooperation of local school boards and administrators.

In addition, it is also recommended that Federal agencies include members of professional societies in the national science education projects as resources for both expertise and information.

Finally, the ASM would like to commend the efforts of those involved in Project Kaleidoscope and would strongly advocate the inclusion of more precollege science and mathematics in the overall plan. Virtually all of the recommendations can apply to this population. We firmly believe that the recruitment of underrepresented groups must begin at the earliest possible stage of learning and must be supported at every level, including the undergraduate years and precollege years.

Thank you for the opportunity to testify, and I would be pleased to answer questions later.

[The prepared statement of Dr. Stokes follows:]

STATEMENT

OF THE

AMERICAN SOCIETY FOR MICROBIOLOGY

Presented by

Gerald V. Stokes, Ph.D., Chairman,
Committee on the Status of Minority Microbiologists
of the Public and Scientific Affairs Board,
American Society for Microbiology
and Associate Professor of Microbiology,
George Washington University School of Medicine
Washington, DC

before the

Subcommittee on Investigations and Oversight

July 11, 1991

AMERICAN SOCIETY FOR MICROBIOLOGY • 1325 Massachusetts Avenue, N.W. • Washington, D.C. 20005 • (202) 737-3600

Mr. Chairman and members of the subcommittee, my name is Gerald V. Stokes and I am Chairman of the Committee on the Status of Minority Microbiologists of the Public and Scientific Affairs Board of the American Society for Microbiology and the ASM representative to the National Life Science Education Summit. I am also Associate Professor of Microbiology at the George Washington University School of Medicine. The American Society for Microbiology is the largest life science society in the world with a membership exceeding 38,000. A major goal in the ASM's strategic plan is to " develop ways to identify, attract and provide better opportunities for underrepresented groups to achieve their full professional potential in the microbiological sciences." This work has been achieved through initiatives of ASM's boards and committees and through collaborative efforts which have included many other life science organizations.

The Project Kaleidoscope Report and that of the National Life Science Education Summit both point out the importance of recruiting and retaining underrepresented minorities in science at the undergraduate level and as you are aware, there are many programs in place that are striving to accomplish this task. The ASM, for example, played a major leadership role in the organization and sponsorship of the National Life Science Education Summit or "Wingspread Conference" in Racine, Wisconsin in February of this year . This event, the first of its kind, was initiated by the ASM and was attended by representatives of thirty life science organizations whose combined membership nears a half million scientists and science educators. The report from the National Life Science Education Summit supports many of the recommendations of the Project Kaleidoscope report; particularly its emphasis on strengthening undergraduate science and math education. The Summit report goes even further to call attention to the need to improve pre-college science education and to encourage underrepresented groups to pursue careers in the life sciences.

The National Life Science Education Summit was formed to pool the efforts and resources of the diverse life science community into one single endeavor. The Summit participants agreed to establish a life science network, called the Coalition for Education in the Life Sciences (CELS); to identify the organizations and resources to bring about formulated strategies; and to generate a national platform for the life sciences. The full report of the Life Science Education Summit has been submitted for your review and additional copies are available from the Office of Education and Training at the ASM.

A second example of ASM's efforts, is the Undergraduate Faculty Enhancement program funded by NSF. This program promotes undergraduate faculty and research scientists interaction for the purpose of improving undergraduate microbiology education. The program sponsors summer fellowships for undergraduate faculty at a research institutions.

Another example is the Minority Student Science Careers Support Program (MSSCSP) which encourages underrepresented minority students who are interested in science to pursue careers in biological research. The program has four components: a Visiting Scientist Program, Summer Research Fellowship Program, Travel Awards to the ASM General Meeting and a Biological Careers Factual Exchange (BIOFAX), a national clearinghouse of information on financial and training programs for students in the sciences. This program is funded by the National Institutes of General Medical Sciences' (NIGMS) through its Minority Access to Research Careers (MARC) Program.

The MSSCSP has been quite successful by working with accomplished students on an individual basis. However, as we all know, by the time a student has chosen to continue his or her education beyond high school, he or she may not be adequately prepared to pursue an undergraduate science degree. The specific skills needed to do science and to do it well are developed at a young age. In addition, many undergraduate students have already made the decision for or against science as a career. To recruit students in science, particularly underrepresented minority students, emphasis must be placed on better preparation at the earliest possible level.

In recommending changes in Federal programs, particularly those of the National Science Foundation, the life science community, based on the results of the National Life Science Education Summit, recommends a revised academic reward system that recognizes teaching and community outreach services to be as important as research activities. Teaching, community outreach and research should be rewarded equally. Without the collaborative efforts of the research and educational communities, the number of U.S. research scientists will continue to diminish. Professional societies can be used as the impetus for these rewards and recognition.

Another role of the NSF should be to serve as a catalyst for the interaction and cooperation of the teacher, school administrator and scientist in efforts initiated by professional societies and other organizations. Very few programs, especially those requiring the participation of teachers can have any success without the cooperation of local school boards and administrators. In addition, it is recommended that Federal agencies include members of professional societies in national science education projects as resources for both expertise and information.

As we see it, the National Science Foundation must take the lead in supporting the efforts of The Coalition for Education in the Life Sciences (CELS) and organizations like it that would establish guidelines for improving undergraduate curriculum in the life sciences as well as a national clearinghouse of life science education programs. The clearinghouse can also assist with the dissemination of federally-funded grants, awards and scholarships.

The NSF must also support grassroots efforts since it has been found that educational programs initiated by community-based organizations are key to recruiting underrepresented minorities in the sciences. Community-based organizations, such as churches, boys and girls clubs and community centers have a strong involvement in and are better connected to these communities.

Finally, the ASM would like to commend the efforts of those involved in Project Kaleidoscope and would strongly advocate the inclusion of pre-college science and mathematics in the overall plan. Virtually all of the recommendations can apply equally to this population. We firmly believe that the recruitment of underrepresented groups must begin at the earliest possible stage of learning and must be supported at every level including the undergraduate years and beyond. Thank you for the opportunity to testify and I would be pleased to respond to any questions.

TESTIMONY OF DR. JANE MARGARET O'BRIEN, PRESIDENT, HOLLINS COLLEGE, ROANOKE, VA

Dr. O'Brien. Mr. Chairman, my name is Dr. Jane Margaret O'Brien and I thank you for inviting me to participate today in this oversight hearing.

I have been asked in particular to address the issues of recruitment and retention of women in science at the undergraduate level, and to make recommendations for changes in Federal programs that would likely increase the participation of women in science.

My impressions are shaped first by the fact that I am a woman scientist with an undergraduate degree in biochemistry from an historically women's college; second, by my 12-year background in teaching and research at an undergraduate liberal arts institution; and third, by my new appointment as president of a women's college, Hollins College, with a 150-year tradition of commitment to encouraging women's achievement in the sciences.

Women today constitute 45 percent of the total work force. Yet in 1979, women accounted for 9 percent of the science and engineering work force. By 1986, this had increased to 16 percent, and the latest indicators are that we are up to 18 percent. These numbers suggest that we have made significant progress in recruiting and retaining women in the sciences. This is true both at the baccalaureate level and at the doctorate level, where respectively one-third and one-quarter of the degrees in the sciences are now being awarded to women.

Two types of institutions have been particularly successful in educating women in the sciences: the so-called Liberal Arts I colleges and the Research I universities. Liberal Arts I colleges rank first overall in the production of science baccalaureates and first in the production of women science graduates.

Mr. Nagle. Tell me what a Liberal Arts I college is.

Dr. O'Brien. A classification done by the Carnegie Foundation for teaching in 1986 classified institutions as Liberal Arts I if they were less than 2,500 in size, predominantly undergraduate in composition and did not give more than 50 percent of their degrees in occupational or professional fields. Most of the institutions represented today are Liberal Arts I.

Mr. Nagle. You used another term, too, Research I?

Dr. O'Brien. Research I universities are those that have—I think it is above $55 million given per year for the purposes of research, and have predominantly, I would hate to give the number, but a certain number of Ph.D.s that are granted per year in the sciences.

These are specific classifications and I use them because they were used in the Project Kaleidoscope report.

With only 3 percent of the undergraduate enrollment, these colleges, which many of us represent today, award 10 percent of the Nation's baccalaureate degrees in the natural sciences and mathematics each year. Close behind are the Research I universities.

Women's colleges, primarily a subset of the liberal arts colleges, have had a particularly important role in the production of women scientists. The proportion of women science doctorates earned by graduates of women's colleges has been historically and still remains almost twice that of coeducational counterparts.

Of all the explanations which might help us to understand this, none is more intuitively plausible and more statistically valid than the correlation developed by Dr. Elizabeth Tidball of George Washington University Medical Center, supporting the direct relationship between the number of women faculty members at an institution and the number of women students who subsequently obtain doctorates in the natural sciences.

It is in the women's colleges where women faculty members are most numerous, approximately twice as prevalent as in coeducational institutions. The imprinting of young women scientists on women mentors is the most directly understandable and verifiable fact we know about women's career choices in the natural sciences. This simple fact should guide us in planning for improving the recruitment and retention of women in the sciences.

From this, there are three suggestions I will make which can directly and rather simply affect increased involvement of women in the sciences. First, we must encourage women faculty to stay in the sciences and encourage new women Ph.D.s to join us, to help us build our network of women scientists.

In the established NSF faculty development programs, including visiting professorships for women and career advancement awards, which specifically help faculty members to gain new skills and to build important community networks in the sciences, encourage more mentoring between liberal arts college faculty, particularly women's colleges which have the greatest concentration of women faculty members.

This parallels a recommendation from the Project Kaleidoscope report.

Secondly, we must encourage mentoring of women students by women faculty. Mentoring is a long-term commitment, and I will second Professor Doyle's recommendation made earlier that the very valuable NSF REU program be reconsidered and restructured more specifically to encourage mentoring within institutions, especially women students by women faculty members.

Thirdly, set the example. The more visibly that the National Science Foundation and other national science organizations show all of us, faculty and students alike, that women scientists have a voice in policy, the more eagerly we too will work to plan for the best learning communities.

I close by thanking you for this opportunity to address you.

[The prepared statement of Dr. O'Brien follows:]

TESTIMONY

Jane Margaret O'Brien
President, Hollins College
Roanoke, Virginia

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

July 11, 1991 hearing on
"TRADITIONAL AND NONTRADITIONAL SOURCES
OF FUTURE RESEARCH SCIENTISTS"

INTRODUCTION

I am pleased to participate today in this oversight hearing on "Traditional and Nontraditional Sources of Future Research Scientists" held before the Subcommittee on Investigation and Oversight for the U.S. House of Representatives Committee on Science, Space and Technology. I have been asked in particular to address the issues of recruitment and retention of women in science at the undergraduate level and to make recommendations for changes in Federal programs that would likely increase the participation of women in science.

Three perspectives inform my comments. First and foremost, I am a woman scientist with a personal understanding of the problems of recruitment and retention of women in science at the undergraduate level. My undergraduate training began at the University of Delaware, which boasts one of the finest undergraduate chemistry programs in the country. Unfortunately, I found myself uncomfortable and discouraged as one of two women in a class of over 100 chemistry students in organic chemistry. After the first exam, I came to the painful realization that being so obvious by gender was no advantage in a classroom where exams were returned in order of descending grade. It made no difference that I ended that course with a B. What did matter to me is that most of the class members had a sense of my class standing, and that I had a sense of my difference. I transferred after that semester, and purposefully chose a liberal arts college with a strong commitment to the education of women.

Secondly, with the exception of my freshman year, I have spent my entire academic career at liberal arts institutions. Sixteen years ago, I received my undergraduate degree in biochemistry from Vassar College. And for the past eleven years I have been a faculty member at Middlebury College, where I was the first woman hired and tenured into a permanent faculty position in the Division of Natural Sciences. Middlebury College has a strong tradition in the sciences and, yet, like most liberal arts colleges, recruitment and retention of women in the sciences is a significant issue especially in the disciplines of chemistry, physics and mathematics where women are traditionally underrepresented.

Thirdly, I now speak as the president of Hollins College, a liberal arts college dedicated to the education of women. As one of ninety-three women's colleges in the country, Hollins has a particular stake in understanding the recruitment and retention of women in undergraduate science education. It is women's colleges like Hollins who have succeeded not only in building a strong pool of women graduating with degrees in the sciences, but who have excelled especially in preparing women who subsequently pursue doctoral study in the sciences. Altogether, six traditionally women's colleges, including Barnard, Mount Holyoke, Smith, Wellesley, Ratcliffe and Vassar, form the core of colleges who collectively have produced the greatest number of women Ph.D. scientists. And although these schools have set the highest standards for educating women scientists, there are another 10 women's colleges, including Hollins College, who have collectively produced half again as many women Ph.D. scientists.

In her treatise "Doctoral Productivity of Women's Colleges," Carol Fuller of the Independent Colleges Offices in Washington, D.C., shows that the proportion of women's science doctorates earned by graduates of women's colleges is twice that of their coeducational counterparts, both for doctorates awarded over the period 1961-1980, as well as for the doctorates earned over the period 1970-86.[1] This information is particularly significant because it establishes unequivocally that women's colleges are as important today as they have been historically in achieving the highest success in educating our brightest women scientists. During the fifteen year period from 1960-76, fully one-half of our nation's women's colleges began recruiting and admitting men, thereby changing their status to coeducational. Yet the data set for 1970-86, extending ten years beyond this most dramatic change shows with consistency that *women's colleges are twice as likely as coeducational institutions to produce women scientists who subsequently pursue a doctorate*.

This distinction is not surprising to anyone who knows M. Elizabeth Tidball's statistics on women's colleges. Dr. Tidball, Professor of Physiology at the George Washington University Medical Center, has published widely on the collegiate environments most conducive to the development of high-achieving women and men. She has developed a statistical correlation supporting the direct relationship between the number of women faculty and the number of women students who continue in post-college achievements. For both women's colleges and for coeducational institutions, the number of women achievers correlates positively and similarly with the number of women faculty members. This relationship has been established specifically for women faculty and women graduates who subsequently earned a research doctorate in the natural sciences.There are, then, two caveats which explain the special environment in women's colleges. First, women faculty members are twice as prevalent in women's colleges as in coeducational colleges. Secondly, there is no statistically significant relationship between women achievers and the number of male faculty.[2]

Such correlations between women science teachers and women in the sciences have not been developed for other educational sectors, but it would seem unlikely that only the ranks of the highest-achievers would be affected so significantly. I have experienced this in my own education as well as through the teaching of my women students. The presence of women in the sciences will encourage the participation of other women and this, above all, should guide our nation's planning for recruiting and retaining women in the sciences.

RECRUITMENT AND RETENTION OF WOMEN IN SCIENCE

The recently released Project Kaleidoscope report, funded by the National Science Foundation and coordinated through the Independent Colleges Office, states succinctly the importance of recognizing the inevitable link between science education and our nation's performance in a world of sophisticated technologies, which in turn are increasingly used as the basis for indicators which measure national progress and health:

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[1] The data is normalized for number of baccalaureates; for 1961-80 doctorates the baccalaureates awarded from 1956-76 were compared; for 1970-86 doctorates the baccalaureates from 1970-82 were compared.

[2] Tidball, E. "Women's Colleges: Exceptional Conditions, Not Exceptional Talent, Produce High Achievers," in Educating the Majority, Pearson, C.S., Shavlik, D.L. and Touchton, J.G., eds. Macmillan, NY 1989

> It is clear that the U.S. education enterprise, particularly in mathematics, physical sciences, and engineering, is seriously underperforming. Measures of trade balances, patent activity, technical specialists per capita, and research and development expenditures reveal that this nation incurs serious penalties from these failings.

Senator Albert Gore, speaking in 1990, stated the argument in terms of our nation's competitiveness:

> We need action soon. More and more, America's competitiveness depends directly on the men and women who develop and apply new technologies. Our health depends on researchers finding new ways to cure disease. The quality of our environment depends on scientists and engineers finding new ways to protect our planet. So many of the questions we face today require scientific and technological answers. We need to ensure that we have the men and women to provide those answers.

It is implicit from Senator Gore's remarks that education is at the root of ensuring our workforce. And the expectation is that our nation's competitiveness will depend on the participation of men *and women* as contributors. Women today constitute 45% of the total workforce. In 1979, women accounted for 9% of the science and engineering workforce. By 1986 this had increased to 16%. Where women are clearly the most underrepresented in this sector is in engineering, where only 1 out of every 25 engineers is a woman. In the sciences alone, women are more represented and range from a low of 12% of the environmental scientists to 45% of psychologists. Considering the sciences alone, one in every 4 employed scientists in 1986 was a woman.[3]

These numbers suggest already that we have made significant progress in recruiting and retaining women in the sciences. Indeed, this is true, both at the baccalaureate level and at the doctoral level. Today one-third of the baccalaureate degrees in the sciences are awarded to women. The Project Kaleidoscope report makes a strong case for the particular role of two types of institutions in educating women at the undergraduate level: the so-called "Liberal Arts I Colleges" and the "Research I Universities" as defined by the Carnegie classification for colleges and universities, representing 142 and 70 institutions, respectively. Independent Liberal Arts I colleges rank first overall in the production of science baccalaureates and first in the production of women science graduates. With only 3% of the undergraduate enrollment, these colleges award 10% of the nation's total baccalaureate degrees in the natural sciences and mathematics each year. Close behind are the Research I Universities. And as previously noted, the women's colleges have had a unique role of their own as a subcategory of the Liberal Arts I institutions.

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[3] National Science Foundation, "Women and Minorities in Science and Engineering," 1988

At the doctoral level, no graduate schools were available to women wishing to receive a degree prior to the 1880's. By 1920, only 15 institutions had granted 5 or more Ph.D.s to women in the sciences. During the ensuing decade, 627 of the doctorates in the sciences were earned by women, or 11% of the total.[4] This percentage has held relatively steady until the past three decades. By 1987, women earned 27% of the doctorates in the sciences.[5] However, a closer look at the data shows that this increase in the representation of women is determined at least in part by an unfortunate correlator: the declining number of men receiving doctorates.

To improve recruitment and retention of students in the sciences, the Project Kaleidoscope report recommends that we consider changes which will significantly change the appearance of the science classroom. A number of learning models are highlighted in the report, including highly interactive, experimentally based curricula which blur the restrictive distinctions between pedagogy and content by making the laboratory the classroom. This environment, modeled after the progressive liberal arts classroom, works for women as well as men:

> It is now clear that women can succeed in great numbers in science and mathematics. The success of women in science and mathematics is greatest in settings --- both single-sex and coeducational --- characterized by the kinds of learning communities described in this report. These settings warm the chilly climate for women so often noted at all levels of education in this country.

The learning communities described in Project Kaleidoscope are reminiscent of the successful strategies which have been used at earlier ages to engage young girls in science. Patricia Campbell describes some of the "community" aspects which make science acceptable to young girls considering math and science careers, including:[6]

- Emphasizing career exposure, not career choice. **That is, talking with scientists, not talking about scientists.**

- Involving girls in activities that reflect the work of people in different science and math careers. **That is, participation in hands-on activities.**

- Reducing the isolation frequently felt by girls who are already interested in math and science. **That is, allowing for a conversant community.**

I believe that we are on the verge of understanding ways in which recruitment and retention of women in the sciences can be achieved. But we need to consider always the *whole* picture of women in science, including the pre-college years and the post-college years, if the ultimate goal is to bring an underutilized human resource into the workforce. One of

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[4] Tidball, E. in "Women's Colleges and the Education of Natural Scientists," presented October 1987, Boston Science Museum

[5] National Research Council, "Doctorate Recipients from United States Universities," 1987 Summary Report

[6] Campbell, P.B. "Girls and Math: Enough is Known for Action," WEEA Digest, Department of Education, 1991

Hollins' alumnae, Dr. Mary Beth Hatten, recently shared some of her thoughts about emerging career issues as a woman scientist now working to educate our next generation's scientific minds:

> Twenty years after being graduated from Hollins, I find myself obsessed with two occupations, caring for my eight year old son and pursuing a career as a neurobiologist. In the latter, I run a large laboratory of young scientists at Columbia University whose work is directed toward understanding how immature nerve cells establish the pattern and connectivity of the brain.
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> Over the past few years, as our work has gained international recognition, I have often questioned what it means to be a woman in science. Although we all like to argue that it's only the science, not the gender of the scientist, that matters, we know full well that women and men often approach problems differently. Moreover, it is tacitly understood that the most successful women are those who can provide the best imitation of a man. Having reached the mid-career milestones, I find myself wanting to find ways to affirm, and even institutionalize, a "woman's approach" in science.
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> What is a woman's approach? At this stage, it's easier to define what it is not, than what it is. It is not "bottom line", not "winner take all", not "all or nothing", not "publish or perish", not "bull and bearish", not a "competitive edge" or "you are what you earn", and definitely not a game of basketball, tennis or golf. It is a longer view, a willingness to take on problems that are not immediately resolvable. It is being able to say "I'm going home to see my children" when a deal is on the table.
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> Several weeks ago, I received an invitation to a meeting of the tenured women professors of Columbia University. Although very active a decade ago, this group had not convened recently, not in the time I have been at Columbia. I felt an intense curiosity as to who these women might be, and how they had addressed their own questions.
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> As I walked into the lounge of Philosophy Hall, a grand old reading room, I was struck with a feeling that I had not felt for a very long time. I realized it was a feeling that I first found at Hollins, a feeling that has been hard to come by since, of unconditional support for women. This was not a man's world. For one thing, the chairs were in a circle. For another, the issue was not whether women still have difficulties developing successful careers, but how to address these difficulties.
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> One by one, the women, Professors of Biophysics, Romance Languages or Law, rose with their lists of concerns voiced by younger women in starting, developing and maintaining academic careers. The discussion went on for hours, each point pounding the realization that in the 1990's the uncertainty about how to foster a woman's career and personal development is greater than it was a decade ago.
>
> Why is that? There are no rules for women. Most often, the pathway is ad hoc, owing to different levels of acceptance of women and to different male codes of behavior in different fields. Then, too, there is the most ad hoc arrangement of all, the logistical nightmare of juggling a career and children. More women drop out at critical points, just after college, just after graduate school, than men, and

> there are no established mechanisms for coming back. Moreover, there is little information to define accurately the problems women face in their careers and a lack of public resolve to address these problems.

Clearly the issues of women in science extend beyond the classroom, no matter how imaginative we become in designing learning communities. We need to recognize the special needs of women in order to accommodate their learning and longevity in the sciences. Our approach must be consistent and, above all, respectful of the fact that there will probably be, at least for many women, a "woman's approach" in science.

RECOMMENDATIONS FOR FEDERAL PROGRAMS TO INCREASE THE PARTICIPATION OF WOMEN IN SCIENCE

I offer three recommendations for improving the recruitment and retention of women in the sciences:

Recommendation #1. The NSF Visiting Professorship for Women is a valuable program which helps women faculty members to gain new skills and to build important community networks in the sciences. I urge you to consider expanding this program to offer more opportunities for women, and to consider more significantly exchanges between strong undergraduate institutions. This recommendation parallels in principle Recommendation #5 in the Project Kaleidoscope report which encourages the establishment of a faculty development program between strong undergraduate institutions, broadening the current Research Opportunity Awards (ROA) Program which enables undergraduate faculty members to do research at major universities.

Within our nation's colleges, a strong faculty of women scientists is developing. Women faculty are most highly represented in the women's colleges, and secondly within the liberal arts colleges. This resource could be shared with other undergraduate institutions if a program can be developed specifically to support exchange. Furthermore, by broadening the guidelines beyond research to include projects related to the study of educational methods, particularly those projects which directly seek to understand and encourage retention of women in the sciences, a means would be provided for women formally to educate others. It is my strong belief that women faculty have both a strong interest and a considerable knowledge about these issues.

Recommendation #2. The Research Experiences for Undergraduates (REU) Program should receive an expanded level of support. This concurs with the recommendation offered by Robert M. Gavin to the Subcommittee on Science in his March 12 testimony. In the current REU competition, the principal investigator must have a project(s) that will accommodate ten students. Furthermore, the requirement that half of the students be from off-campus does not foster the mentoring relationship of community that we are striving to create in the sciences. Rather, preference might be indicated for proposals wherein half of the students are women and women faculty are involved in the project, in that way encouraging a climate wherein women faculty can provide a critical model for young women with an interest in the sciences. I specifically choose the route of "preference" rather than "requirement" to encourage rather than mandate that academic communities think about their own campus communities in which women scientists, teachers and students, pursue their work.

Recommendation #3. At some point, it is critical for Federal programs to include more women in the top levels of administration and for these women to be visible to women faculty and students. I commend the National Science Foundation for working diligently to include women on their staff and for keeping women actively involved on review panels. I also bring to your attention the composition of the Project Kaleidoscope Executive Committee and the Advisory/Action Committee. Women are represented in a significant way on these committees, as they need to be on any committees overseeing recommendations for the sciences. I hope I have convinced you by the numbers that I have presented that there are women who are scientists and that our nation has made considerable progress in attracting women into the sciences. Many of us have ideas about issues for women in the sciences and many of us can work formally or informally to encourage Federal programming which is sensitive to the fact that there will probably be, at least for many women, a "woman's approach" in science.

CONCLUSION

I close by thanking you for this invitation to appear before this Subcommittee and having the opportunity to express my views about the recruitment and retention of women in the sciences. In assuming my new responsibilities this past week as the President of Hollins College, I am myself following a fellow scientist and chemist. Dr. Paula Brownlee, president of Hollins College for nine years, was appointed President of the Association of American Colleges in September, 1990. We are both women who pursued our professional route in the sciences, both proof that there is within the educational system a path that works for women interested in the sciences. The challenge before all of us now is to make that path wider.

Mr. **Nagle**. Thank you.
Dr. Gentile.

TESTIMONY OF DR. JAMES M. GENTILE, PROFESSOR OF BIOLOGY AND DEAN OF THE NATURAL SCIENCES, HOPE COLLEGE, HOLLAND, MI

Dr. **Gentile**. Thank you, Mr. Chairman. I am very pleased to participate today in this oversight hearing.

My name is Jim Gentile. I speak to you as a biologist who has been an active teacher-scholar with undergraduate students for over 15 years, and as an administrator who understands the commitment necessary for changes that will enhance opportunities for women and minority students.

That I am a white male from a coeducational, predominantly majority institution underscores the fact that institutions such as Hope must play a critical role in the training of women and minority students. Hope College has a strong tradition in training students who obtain advanced degrees in science and mathematics.

We are now dedicating significant efforts to meet the need of women and minority students in the sciences and to build and retain a student body that reflects current population demographics in Western Michigan.

The first step necessary for any institution to make inroads into the education of women and minority students is commitment. Insufficient commitment is generally a greater barrier to success than inadequate resources. Liberal arts institutions such as Hope College are among those institutions that have expressed commitment and developed the programs necessary for success with these students.

It is my firm belief that liberal arts schools will lead the way in the future in the continued development of successful programs that can serve as models for all institutions. Using some programs now in place at Hope, let me give you some personal examples of how institutional commitment can be translated into action.

To encourage science career opportunities and to recruit minority students into the sciences, we have entered into a unique partnership with the University of Michigan Medical School in which we jointly recruit and provide fiscal resources for minority students to pursue undergraduate studies at Hope followed by guaranteed graduate work at the University of Michigan.

As undergraduates, the students are nurtured in faculty and student led support groups, they pursue biomedical research with faculty from both institutions, and following graduation from Hope, they are admitted with scholarship for graduate study at the University of Michigan Medical School.

This program has proven extraordinarily successful in attracting promising students and giving these students a guaranteed career opportunity at a very early stage of their education and of sustaining these students in a continuum from undergraduate through graduate years.

A second example involves partnerships that improve student interest in science at the elementary school level. Our Partners in Science program, funded through a generous grant by the Kellogg

Foundation, Hope College and three local school districts, allows in-service elementary school teachers to work side by side with Hope College students who are preparing for a teaching career. Teachers and students take classes together, do joint hands-on laboratory work, and together bring hands-on laboratory modules back into the elementary classroom for the elementary students.

Included in this program are special Saturday and evening programs for girls and minority students and their families. These emphasize opportunities in science and encourage the young students to pursue careers in science and mathematics.

Thirdly, using funding from the GTE Foundation, the NSF, NIH and the Howard Hughes Medical Institute, we have developed summer programs that allow women and minority students from area high schools and Hope College undergraduate students to work collaboratively with one another and with Hope faculty in research laboratories. The high school students simultaneously take enrichment courses in English, mathematics and science to enhance opportunities for future college success.

Lastly, along with nine other liberal arts institutions, Beloit, Carleton, Grinnell, Kalamazoo, Knox, Macalester, St. Olaf, Rhodes, and Trinity University, and two distinguished private universities, The University of Chicago, and Washington University-St. Louis, we are members of the Pew Mid-States Consortium for Science and Mathematics.

We have developed collaborative programs that enhance curricular development. A central focus is aimed toward improving entry level courses and devising different avenues in the curriculum, multiple entry points, through which students can travel in their pursuit of science and mathematics careers.

We have also devised teaching workshops to enhance faculty accountability to women and minority students. For example, a woman Hope faculty member and a male faculty member from Carelton College are now organizing a teaching enhancement workshop focused at changing the classroom climate to meet the needs of women and minority students on our campuses.

These are but a few examples of efforts that have significantly strengthened educational opportunities at Hope for women and minority students, while also helping all students to enrich their vision of careers in science and mathematics. There are also examples of creative opportunities available to all institutions serious about developing approaches to catalyze the teaching of women and minority students.

Let me summarize by saying that among the lessons learned from Project Kaleidoscope is that faculty and administrators from predominantly undergraduate institutions are eager to be involved in national efforts to reform undergraduate science and mathematics education, and are equally eager to develop and sustain programs that foster science career opportunities for women and minority students.

We realize that the ultimate solution in achieving our goals is to not rely solely upon resources from the National Science Foundation and other Federal agencies. Rather, we must foster partnerships between the public and private sectors and committed academic institutions to sustain our efforts over the long haul.

For example, a Federal program to promote linkages between faculty from minority and majority institutions or between faculty from coeducational and single-sex institutions, and allow for unique consortial arrangements between such schools would be a catalyst for action.

We look forward with enthusiasm to learning from our colleagues at minority and single-sex schools and to hearing a vision of what works for women and minority students with one another and with all. Thank you.

[The prepared statement of Dr. Gentile follows:]

TESTIMONY

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TRADITIONAL AND NONTRADITIONAL SOURCES OF FUTURE RESEARCH SCIENTISTS

July 11, 1991

UNITED STATES HOUSE
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

Subcommittee on Investigations and Oversight

Speaking for
Project Kaleidoscope
The Associated Colleges of the Midwest
The Great Lakes Colleges Association
The Central Pennsylvania Consortium
Reed College, Allegheny College

INTRODUCTION. I am very pleased to be invited to participate today in this oversight hearing on traditional and nontraditional sources of future research scientists held before the Subcommittee on Investigations and Oversight of the House Committee on Science, Space and Technology. For Hope College; for our peer institutions within the Associated Colleges of the Midwest, the Great Lakes Colleges Association, the Central Pennsylvania Consortium; for Reed College, Allegheny College and the other institutions served by the Independent Colleges Office; and for all students, faculty, and administrators of institutions that have actively participated in Project Kaleidoscope; the National Science Foundation and other agencies within the Federal Government are significant partners with us in our efforts to attract and sustain student interest in science and mathematics. We recognize and appreciate the central role this subcommittee plays in catalyzing the relationships between the government and predominantly undergraduate institutions such as Hope College, and in ensuring that those relationships are productively focused.

My comments reflect my 15 year history as a teacher-scholar-administrator at a liberal arts institution. I received my undergraduate degree in the biological sciences from St. Mary's College in Minnesota and my Ph.D. in genetics from Illinois State University. In 1976, following postdoctoral studies at Yale University, I became a faculty member at Hope College, and I assumed the position of dean of the natural sciences at Hope College in 1988. I have worked with undergraduate students continuously throughout my career. Almost one-half of the nearly 100 undergraduate research students from my laboratory have gone on to professional careers in science after receiving advanced degrees. Over 60 of my undergraduate research students have been women. I speak from experience in the classroom and laboratory, and I speak with an understanding of the importance of establishing institutional priorities for strengthening science and mathematics programs. I am particularly excited about appearing before this committee and for having the opportunity to express my views on issues dealing with this particular topic, the education of women and minority students in the sciences. This is topic of special importance to me. I have dedicated a significant portion of my energies to this need and I pledge to continue my efforts. Hope College is committed to meeting the needs of women and minority students. Approximately 60% of Hope students are women, and we are located in a western Michigan community that boasts a strong Hispanic heritage More than 25% of the local high school students are minority students. Let me cite some examples of our recent endeavors to enhance opportunities for women and minority students in science. With support from the GTE Foundation, and building upon the success of two previous NIH Minority Student Research Apprenticeship Program awards, we have developed a program to provide local minority high school students with an extensive exposure to science and mathematics by providing them with enhanced learning opportunities in the summer and academic year in english, mathematics and science, and by incorporating them into the research laboratories with Hope faculty and students. This program interfaces with an existing Upward Bound Program which is designed to increase the probability that women and minority students will attend and successfully finish college. These programs have proven remarkably successful. For example, all of the students who participated in either the NIH or GTE programs have enrolled in college and the six students from our first year of the program have all graduated college with a degree in science. We are now in a new phase of our program and, with recent support from the Howard Hughes Medical Institute, we will expand our efforts to reach more students. Hope College has also established a partnership with the University of Michigan to provide qualified minority students at Hope with funding at both institutions, priority admission for graduate study at the University of Michigan Medical School and research opportunities on both campuses. In addition, we have recently developed a recruitment and retention program for women and minority students that involves a faculty member as a special science recruiter to assist us in encouraging these students to attend Hope College and other faculty members as mentor-leaders support groups for minority students which they can utilize throughout the four years at Hope College. I must emphasize that Hope College is a co-educational institution that is not blessed with a high enrollment of minority students. Nevertheless, we are an institution that is dedicated to making changes that will enhance opportunities for our women and minority students in science and mathematics, that will encourage more women and minority students to pursue higher education at Hope and elsewhere, and will enrich the bond between Hope College and the surrounding community.

Today in this Oversight Hearing on traditional and nontraditional sources of future research scientists I would like to emphasize three points and make the following recommendations:

Point 1). The recruitment and the retention of women and minorities into science at the undergraduate level;

RECOMMENDATION: **Increased resources be allocated to the NSF Curriculum and Course Development Program. Special emphasis must be placed on entry-level science and mathematics courses and programs that seek to develop multiple entry points for students into science and mathematics curricula. Because of the wealth of institutions seeking to change to meet future needs for women and minority students, many smaller awards should be given rather than fewer, centralized large awards.**

RECOMMENDATION: **Increased attention must be paid to establishing connections between colleges and the elementary and secondary school communities. Programs must be continued to be shaped so that students are made aware of the possibilities and excitement of scientific careers well in advance of their college years. This is the first, important step in recruitment.**

Point 2). The central role of all faculty members in mentoring women and minorities in science;

RECOMMENDATION: **The NSF Faculty Enhancement Program should be provided with increased funding and funds should me made available to support faculty to develop teaching and activities that will lead to help increase faculty accountability to women and minority students and will lead to enhanced community for all students, particularly women and minority students.**

RECOMMENDATION: **Establish a National Doctorate Opportunities Program to expand existing doctoral development efforts and create initiatives to increase the number of women and minorities receiving doctorates. Women and minority undergraduate students must know that career opportunities if they respond to our call. Women and minorities play vital roles in working with students and in helping dedicated White and male faculty in reaching out to women and minority students. We need to establish a critical mass of qualified women and minority faculty members.**

Point 3). The importance of co-educational and majority institutions to make commitments to programs that enhance opportunities for women and minorities in science.

RECOMMENDATION: **Institutional Environments must be changed if we are to be successful in enhancing opportunities for women and minority students. The Research Careers for Minority Scholars Program is an excellent program that must be continued and expanded. Programs must be established that challenge institutions to think comprehensively, and support institutions in their comprehensive efforts.**

RECOMMENDATION: **THE NSF and other federal agencies should establish programs that foster partnerships between individuals and between different types of institutions to strengthen opportunities for women and minority science students. Structures must be implemented to link people and to provide a network for strategies that work. Monies should be set aside in the course and curriculum program for joint projects between minority and majority institutions. Furthermore, appropriate oversight must be maintained so that different Federal agencies and different arms within agencies can act in a coordinate manner.**

We must have a clear sense of what works in science and mathematics education for women and minority students if the above recommendations are to be successfully implemented. We must have a clear vision of the problems and the potential of women and minorities in science and mathematics, and we must have a articulate plan of how all institutions, particularly co-educational, predominantly majority institutions, can take the steps necessary to ensure that women and minority students on their campus are provided with the best opportunities for success in science and mathematics.

Science and mathematics are created, transmitted, and applied by people. They are fundamentally human activities. If this country is to continue having strong science and mathematics, then human resources - the education and continued engagement of scientists and mathematicians - is almost the only important question.

It is well-documented that women and minorities are severely under-represented in science and mathematics careers. However, while there is general agreement about the importance of increasing the participation of women and underrepresented minorities in undergraduate and graduate education in science and mathematics, there is less agreement about the public and private commitment to provide the financial resources and to develop the policy initiatives necessary if the rate of participation of these two groups is to be improved. The work of the Quality Education for Minorities in Mathematics, Science, and Engineering is a particularly cogent example of how a joint effort can serve to foster a restructuring process to meet the needs of our nation's minority students.

Studies have shown repeatedly that a significant number of predominantly undergraduate colleges, including some Historically Black Colleges and Universities and some women's colleges, have extraordinary success in producing graduates able to move easily into scientific and technological careers. Their success applies as well to minority students and women, and this success can be traced directly to the manner in which science and mathematics education takes place in these colleges. These schools are successful because they have a common denominator of a strong community-based learning environment. This is the crucial enabling factor in the success of historically Black colleges and of other colleges that succeed with minority students, and it is also what propels many graduates of women's colleges to successful careers. Community is attainable by all institutions and it should be sought as a deliberate goal of policy and design in all baccalaureate learning environments.

Science and mathematics education succeeds whenever it takes place within an active community of learners, where students work in groups of manageable size to enhance collaborative learning and where faculty are deeply committed to teaching, devoted to student success, and confident that students can learn. This type of learning is never passive. It is active, steeped in research and experiential from the very first introductory courses to the completion of students' science and mathematics education.

This kind of education simultaneously motivates and empowers students to learn science and mathematics. It enmeshes students within a community that improves the persistence of individuals through the continuity of instructional programs.

POINT 1: THE RECRUITMENT AND RETENTION OF WOMEN AND MINORITIES

The last two decades have produced increased numbers and proportion of women and minority individuals receiving bachelor's degrees. Sadly, in most areas, the increased percentages are due more to declines in the numbers of white males majoring in science and mathematics than to increased participation by women and minorities. The impending shortage of white male students must not be the reason we encourage women and minority students to engage careers. Rather we must foster science and mathematics career opportunities for women and science because it is important for them as individuals, and the wealth of scientific and mathematical knowledge will expand because of their future contributions.

Of the many factors beyond outright discrimination that contribute to the discouragement of women and minority scientists, six stand out. These are:

1. Introductory courses, especially at many large research institutions, apparently serve to discourage women and minorities at a time when they need most support.

2. Women and minority students are a distinct "minority" at every level in most scientific disciplines, resulting in a lack of a critical mass of peers.

3. Because of the lack of women and minority faculty members, few same sex/race faculty role models exist.

4. Women and minority students ask fewer questions or are ignored in courses and engage less often in debate with other students and with faculty members.

5. Highly competitive grading systems result in enhanced frustrations for women and minority students, and they are more likely to blame their own "lack of talent" rather than problems in the classroom or teaching climate as the cause of their perceived unsatisfactory performance.

6. The high levels of frustrations and competitiveness for research funds among faculty provide significant discouragement for women and minority students who are attempting to balance career decisions with "normal lives."

It is relevant to note that all of these factors suggest something about self-concept or self-image. Thus programs and curricular endeavors that are encouraging rather than discouraging, that "cultivate" talents rather than "weed" students, and that promote opportunity and creativity rather than depress career choices and individuality will be the only programs that will succeed in developing a cadre of women and minority scientists and mathematicians who will be vital human resources for the future.

We must concentrate first on courses in the general and introductory area. This is the first place we can make the quest reforms. We have women as entering students and most of our students have minorities as first year students. We must grasp foster their creative energies from the very first day and encourage them in this formative stage of their education if we expect to have a meaningful impact on their career development in science and mathematics.

We must also focus energies on improving elementary/secondary school connections. Volumes have been written about the decline of science and mathematics awareness and abilities of our elementary and secondary school students. Curricula are often out of date and it is rare that students have the opportunity to participate in hands-on experiences that enrich their awareness of science and mathematics and make these disciplines a reality in their lives. Those of us a colleges and universities cannot lament our fate and allow the various sectors of pre-college education to shoulder the entire burden alone. We must find creative ways to improve our connections with local schools and school districts and devise creative strategies to bring all students, particularly women and minority students, to a stage where science and mathematics career opportunities become an expectation rather than an unattainable dream or, in more dire situations, a nightmare.

The disgraceful situation of the small number of women and minority students who are attempting to pursue science and mathematics degrees at majority institutions can be corrected. Science and mathematics departments must implement constructive plans to alleviate the multitude of problems that exist. We must envision introductory courses as an opportunity to recruit. Multiple entry points into science must be developed within each institution. These avenues that allow students different routes through the curriculum to enter science programs are essential if we are to provide opportunities for students with diverse backgrounds. Group-learning and research opportunities for students must be established and maintained to help to sustain students in college, peer-support group structures must be devised, and communities of learners must be nurtured.

As Shirley Malcolm of the AAAS said at the Project Kaleidoscope National Colloquium, "Women and minorities are the miner's canary signalling deeper problems in our programs. If we do not rethink programs and if we continue to depend upon tired strategies of weeding we will certainly face a troubled future."

Clearly, individual academic institutions must shoulder a significant share of the responsibility for change to a system that will be supportive of the needs of women and minority students in the sciences and mathematics. However, beyond a commitment to change, fiscal support for that change must be made available. The NSF-Undergraduate Curriculum and Course Development Program is one key to success. The demand and need for this program has been well-demonstrated, but resources availability has been limited. This program must also have multiple foci. There must be a balance between the large, systemic change efforts that are proposed with those affecting institutions of all kinds - serving a diversity of students.

RECOMMENDATION

I propose that more resources be allocated to the NSF Undergraduate Curriculum and Course Development Program, with special emphasis given to supporting efforts to address problems with entry-level science courses that will serve to cultivate rather than discourage student talent. Furthermore, recognizing that students of promise come to us with different backgrounds and levels of preparations, I propose that many awards of various size be given, rather than fewer, more centralized awards. Many institutions have the dedication, creative energies and vision necessary. Seed monies provided in a dispersive fashion will provide rich rewards for women and minorities nationwide.

Point 2. THE CENTRAL ROLE OF ALL FACULTY MEMBERS IN MENTORING WOMEN AND MINORITY STUDENTS IN SCIENCE AND MATHEMATICS

The development of strong student-faculty relationships is an important component for the success of women and minority students. While it is easy to envision how women faculty or minority faculty members can, and do, provide significant role models for women and minority students, it is important that all science and mathematics faculty be sensitized to the part they must play in the success of all students. This must happen on all campuses. Male, majority faculty automatically provide role models instrumental to the success of male, majority students, These faculty must learn to do so consistently and effectively with women and minority students. They must learn to look at women and minority students when they give lectures, they must call upon these students and expect the students to answer questions, and they must let them know of such expectations. Confidence and expectations must be transmitted to all students. Faculty must work to discard beliefs that minority students cannot do science, because this attitude cannot be hidden from the students and therefore will be fulfilled.

Male, majority faculty must be willing to serve as mentors and must not expect the few women and minority faculty at an institution to take care of all women and minority students. Majority faculty too can be effective role models. If White faculty at Historically Black Colleges and Universities and male faculty at women's colleges can serve as role models for Afro-American and women students, White male faculty at majority institutions can do the same.

A student who has the good fortune to be a member of a science learning community or a partner in a research collaboration is learning more science and has a significantly enhanced chance for a successful scientific career. College faculty must recognize that they are the bridges to the future for their students and that they are pivotal to the success of the learning community. Faculty must help women and minority students see themselves as part of the community of science. That means that faculty must be able to recognize themselves as an integral component of that community and then help students to develop her or his own individual understanding of the nature of the community by understanding the faculty members vision of the community. Science departments must foster the same kind of natural science communities for women and minority students as they do for majority students. Only in this way will we increase the numbers of women and minority students who gravitate towards and remain in science.

Creative activity must be fostered in teaching and learning, as it is in basic disciplinary research.

RECOMMENDATION

I propose that the NSF Undergraduate Faculty Enhancement Program be provided with a significant increase in funding, and that these funds be made available for the support of faculty in developing activities and modes of teaching that will lead to enhanced community for all students, and especially for women and minority students, revitalized teaching, and innovative curricular design. For example, by providing opportunities for White, male undergraduate faculty to work with women or minority teacher/scholar colleagues at other undergraduate institutions for the purpose of synergizing and revitalizing teaching efforts, the NSF will foster ingenuity and transfer creative energies throughout our nation.

Point 3. THE IMPORTANCE OF COMMITMENTS BY CO-EDUCATIONAL AND MAJORITY INSTITUTIONS TO ENHANCE OPPORTUNITIES FOR WOMEN AND MINORITY STUDENTS IN SCIENCE AND MATHEMATICS

As I indicated previously, there is sound and understandable evidence that women's colleges and institutions with a significant base of minority students have exceptional records in attracting and training women and minority students and recruiting them into careers in science and mathematics. There is also a growing wealth of evidence that many co-educational and majority institutions also have a significant record in attracting, and sustaining, women and minority students in science and mathematics. Those institutions in this latter category that have proven most successful include the independent, predominantly undergraduate colleges that already are major players in undergraduate science and mathematics education for all students. Because theirs is a teaching rather than a research-driven mission, these institutions are constituted in ways that enhance the approach to science and mathematics teaching and learning that works well for all students. What works is community based learning, a commitment to meeting each student's needs on an individual basis, and a faculty dedicated to student learning. While this kind of teaching and learning is in some ways more expensive than other less effective modes of instruction, insufficient commitment is generally a greater barrier to success than inadequate resources.

There are many avenues through which all institutions can reach out to the needs of women and minority students. They include: building an attractive and hands-on curriculum; providing multiple entry points into that curriculum for students; promoting and nurturing group learning among students; expecting, recognizing and rewarding faculty for teaching accomplishments in addition to scholarly accomplishments; working with all faculty to enhance their awareness of needs of women and minority students and providing a support structure for faculty and students alike; and helping all faculty to become role models who encourage all students, including women and minority students, to see the wealth of opportunities before them as they pursue their interests in science and mathematics.

Co-educational and majority institutions must also seek creative partnership opportunities to enhance their ability to succeed with women and minority students. Creating and sustaining partnerships not only extends the reach of individual institutions, but also gives participants a sense of being part of a larger vision, of being a piece of the solution to a national problem. Partnerships help sustain attention on issues which require long-term effort; they motivate faculty and administrators to effective action; and they create wider recognition and reinforcement of local successes.

Our experience at Hope College, a liberal arts institution of 2700 students, exemplifies the importance of partnerships in building enhanced educational opportunities in science for women and minority students. Let me give you three examples.

Hope College has entered into a partnership with the University of Michigan Medical School in which we jointly provide financial sponsorship for minority students for undergraduate studies at Hope College, for summer research at Hope College and the University of Michigan Medical School, and for guaranteed admission and scholarship for graduate study in the biological sciences at the University of Michigan Medical School following receipt of the Hope College degree.

A second example involves partnerships that improve student interest in science at the elementary school level. Our Partners in Science Program, funded through a generous grant by the Kellogg Foundation and supplementally supported financially by Hope College and the three local school districts, allows in-service elementary school teachers to work side-by-side Hope College students who envision a career in teaching. The teachers and students take classes together, do joint hands-on work in laboratories and together bring hands-on laboratory modules back into the elementary classroom for the students. Included in this program are special Saturday and evening sessions for young girls or for minority students and their families that emphasize opportunities in science and encourage these students to pursue careers in science and mathematics.

Lastly, along with nine other liberal arts institutions (Beloit College, Carelton College, Grinnell College, Kalamazoo College, Knox College, Macalester College, St. Olaf College, Rhodes College, Trinity University) and two distinguished private universities (The University of Chicago, Washington University-St. Louis), we are members of the Pew Mid-States Consortium for Science and Mathematics. Collectively, and with significant funding from the Pew Foundation, we have developed programs that enhance curricular development as well as research opportunities for students and faculty, and provide an expanded base of learning opportunity and faculty mentorship and vitality for our women and minority student constituencies.

These are but three examples of partnership efforts that have significantly strengthened educational opportunities at Hope College for women and minority students while simultaneously helping all students to enrich their vision of careers in science and mathematics. They are also examples of creative opportunities available to all institutions serious about developing synergistic approaches to catalyze the teaching of women and minority students.

Support for partnerships should be a high priority for public and private funding sources for science and mathematics education. In fact, the public and private funding sources must participate as partners with one another as well as with academic institutions to provide the necessary resources to support the united vision of different institutions.

RECOMMENDATION

I propose that the NSF and other federal agencies look towards establishing programs that will serve to foster partnerships between institutions of different types. For example, partnerships between co-educational and women's colleges, or partnerships between majority institutions and predominantly minority institutions can become keys in establishing mechanisms for enriching educational avenues for all students, and particularly for women and minority students.

Lastly, I urge that appropriate oversight continue to be strengthened and provided so that different Federal agencies, and different arms within individual agencies, are not in direct competition with one another and are coordinated in a fashion that allows synergism of effort rather than a fragmentation of venture.

SUMMARY

Among the many lessons learned from the Project Kaleidoscope endeavor is that faculty and administrators alike are eager to be involved in national efforts to reform undergraduate science and mathematics education. These same individuals are equally eager to develop and sustain programs that will foster science career opportunities for women and minority students on their campuses. The road is hard, but the will is there. Along with my colleagues at predominantly undergraduate institutions, I look forward with enthusiasm to sharing our vision about "What Works" for women and minority students on traditional co-educational and majority campuses with the NSF and other federal agencies and to forming partnerships that will allow us to develop that vision to its fullest potential.

Mr. **Nagle**. If I were a cynic, and I am not, I would take the testimony of all of you collectively, which was well done and which was well prepared—it was a pleasure to have the last two panels in here that have obviously not only written their own thoughts but brought other scientific thought and data to us, it's very valuable and I'm sincere in that.

But it sounds to me like I should go back to the University of Iowa, which I also represent, or Stanford, and tell them to quit trying to do undergraduate teaching, and focus all of our resources on small colleges, minority based, perhaps, because the success stories told by Dr. Stokes and Dr. Cole are quite good.

Are we at a point where the larger universities really should just butt out of this effort? I gather we are getting a lot more success at your level than we are at the University of Iowa. And I'm not saying anything I haven't told the University of Iowa. They're not going to be in the district next year, either. [Laughter.]

I mean, I'm for courage, but not suicide.

Dr. **Cole**. If I could respond to this one, Congressman, no, that is not what we're saying, not from my point of view. We are not talking about either/or. We are not talking about taking from or discouraging the research universities from continuing what they are doing with research and also teaching.

What we are saying to you is that there is a serious problem in this country with the production of scientists and engineers in general, and minorities and women, especially so. The problem is of such major proportions that if we are going to be able to begin to turn that around to address it, we have to give additional resources where the track record and commitment has been greatest.

Mr. **Nagle**. The thrust of your testimony, I think all of you collectively, the thrust of your testimony is that those resources, while they should be small programs and they should be diverse—I understand that and don't disagree with it—they also should be focused predominantly at small universities and smaller institutions, minority institutions and women's colleges, since that's probably where we are going to have the greatest success.

Dr. **Cole**. Those resources—in terms of those outcomes. The graduate education in this country is the best in the world. One of the reasons is that there are some good things that are done at the Federal agencies in terms of how they dispense research funds. So we are not talking about changing that, especially.

What we are saying is that we also have another kind of problem that we need to make sure agencies target resources where they will have the greatest chance of success. If there are institutions that historically know how to approach this particular problem, then resources ought to be directed there to focus on this particular problem.

Mr. **Nagle**. Dr. Stokes?

Dr. **Stokes**. I would like to continue with that line, in that I think we are all saying the same thing. There are roles for both large and small institutions. A common line between the Project Kaleidoscope report and the report that was issued through the Organization of Life Science—the coalition—was the absence of linkages of information and potential between large and small and the role professional societies can play.

I will give you an example. For example, the ASM has over 38,000 members. Through our program, the minority focus program, funded by the NIH, our MSSCSP program, we are able to take applications from minority individuals at both large and small institutions and give those individuals, these undergraduate students, exposure to science, to research atmospheres, in an environment which they themselves would not have an opportunity to take part in.

It is that sort of potential of the professional societies that I would like to stress which we as professional societies can bridge between large and small institutions. It is quite clear that teaching is the main focus at the small institutions.

Teaching is becoming a major focus, an increased focus, at the larger institutions. Part of our report was the emphasis that reward for teaching should be equivalent to, or given greater respect, in terms of promotion, at large institutions as it is at smaller institutions.

I think those are the responsibilities the institutions themselves have to tackle. However, the function of professional societies is to somehow bring the resources of the small ones and large ones so we can work best with what we have.

Mr. **Nagle**. I have the feeling, and I haven't seen the data done on it, I have seen data that indicates that we wash out, change majors, would-be scientists and mathematicians at a higher rate than any other major that walks into a four-year institution. That I know, I have seen the data on it.

But I suspect that if I went to the larger research institutions that are attempting to do undergraduate work, the reason those statistics are so high is because the wash-out rate at those larger institutions is so great, and I am almost tempted to tell anyone who wants to be a scientist or mathematician they should go to Grinnell, go to Luther, or to Hope, rather than elsewhere.

I still worry about that woman student or Black student or Hispanic student in the back row in a class of 500, being taught by a graduate assistant. Some of the testimony you gave—I recognize you are the ones best suited to solve the problem. Is there anything we can do on the other half of this, anything we can have larger institutions do differently than what they are doing?

Dr. **Gentile**. I'll take a stab at that. I think one of the issues is——

Mr. **Nagle**. Because the students are still going to go there.

Dr. **Gentile**. Right. And unless we change something at those very large research institutions that have huge numbers of students—the University of Michigan has well over 40,000—we really are not going to make a significant dent overall in the population nationally. But I think what we must do is work within the change of philosophy of undergraduate education that seems to be prevalent at a lot of those institutions.

There is a lot that perhaps some of the liberal arts institutions and the predominantly minority institutions and the women's colleges can teach one another as well as teach those institutions about what works. Partnerships can be established. I gave two examples of how we are involved with partnerships with three different research institutions, one of them a state school and two of them private.

There are programs that work. There are things we can teach them about what works if they have the commitment to learn and the commitment to change. And I think that is where resources could be put into those institutions, once they have that commitment to work for change.

But just putting resources into the old tried and true methods of education that have proven remarkably unsuccessful to this point in time for women and minority students really is not the best way to go.

Dr. O'BRIEN. I would just second that, and say that I think there has been a tendency to think in education that all of us could do everything well. An institution like Hollins College that has a fully female undergraduate student body does not have a large minority population. At this point I would not encourage Hollins to be looking for funding for minority activities. It doesn't do that well.

What it does well is women's education. And it is to reward those endeavors that makes the most sense, to put the efforts into funding programs that have been shown, emphatically, statistically, to work for us. I don't think that necessarily suggests that other institutions cannot develop their own programs.

Mr. NAGLE. I met with a group of scientists at the University of Iowa. The phrase now is "dead at 30." That means if you are scientists, you have a Ph.D. and if you don't get a grant by the time you are 30 years old you are academically dead.

I met with the head of the neurology department here a few weeks ago, and there is an inordinate amount of time spent chasing research dollars, and it almost seems to preclude the resources to do undergraduate education under the current system. It is almost like you have to be teaching or you have to be in research and purport to be teaching, because it looks good on your curriculum. But you are not really getting it.

Is there a way out of the problem, or is my perception in error?

Dr. O'BRIEN. My sense from being an undergraduate researcher and teacher for 12 years is that I was working 80 to 90 hours a week trying to do all of those things. And you tack on the issue of mentoring, which is very important for women students. The job almost becomes undoable.

I think there needs to be a message that first of all those types of activities that include the breadth that liberal institutions have are very well appreciated. Dr. Light, in the previous testimony, was talking about reward systems. You need to have incentives built in for young faculty in particular.

You talked about the age 30 problem. There is also what I would call the age 40 problem which is that if one does not retrain into the more modern techniques in some of these fields you are out also.

So it is something to appreciate, it is a burdensome profession to go into, and again as Dr. Light said, it has been the Calvinist society ethic that has gotten us through this. Those of us that go into it do have work ethics that are pretty extensive. If the reward is there, I think it's a very valuable profession.

Dr. **Gentile.** I would like to echo absolutely all those remarks and point out something. It doesn't become a very good thing to encourage young students, when you talk about being dead at 30, they say they want to go into science and we talk about the possibility of not having a career at age 30 or 35 or 40.

I don't want to change the mission of research institutions. I think they have a fine mission and they should continue that mission, and they should work it well. But when we get to the point that NSF panels and NIH panels become surrogate tenure and promotion committees for our academic institutions, I think we have a very difficult time ahead of us.

And we are not offering a very promising career to young students, whether they be women, Black, Hispanic, or White, as they want to seek an academic career in science and go on to become a professional scientist.

So I think what we are really looking at is perhaps an overall understanding of what it means to be an academic institution and each institution is going to have to look very seriously at their mission and perhaps redefine that mission in some cases.

Mr. **Nagle.** Just as an aside, totally as an aside, because I don't want to get into it, but you dare not attack the peer process. Everyone is in favor of the peer process. So I think at some point I would like to explore whether or not the way we are implementing the peer process, particularly on research grants, is necessarily as productive as it should be.

I think people burn up more time filling out forms and evaluating other people's projects than they are—but you can't even say that, because it implies that you are against the peer process. But that was an aside.

Let me ask you this. Where do the teachers come from? Where are the teachers going to come from? We are talking about scientists and mathematicians going into industry and everything else. It seems to me there is also a shortage in terms of undergraduate faculty.

Has there been any discussion in your circle in terms of that? Who is going to teach the women students, assuming we do a good job? Who is going to teach the students period? Is there effort of conversation or direction within your circles in terms of that?

Dr. **Cole.** No, that's precisely why we are talking about focusing resources and additional energies on producing more, in this case, minorities, who do go through the system and obtain Ph.D.s so they can be part of those who are replacing the World War II babies who are going to be retiring soon.

We talk about not having enough scientists and engineers in the work force, our faculties are also in 10 years going to be in serious need of replacements, because of people who will be retiring soon. So if we are not addressing those issues right now in terms of producing more, we will be having increased difficulties in finding qualified faculty who will teach minorities and women and who also will fuel the economy that is required for our technical work force.

Mr. **Nagle.** Anybody else?

Dr. **Stokes.** That's a very difficult problem in terms of science education, who will be the teachers. Unfortunately, at the larger institutions, it is the faculty that teach and one of the primary criteria is their potential to draw research funds and to gain professional recognition in the scientific community. The criteria for using teaching or the ability to teach as a primary factor for the hiring of new faculty does not take a high priority in the selection of faculties at the larger institutions.

I am certain some of my colleagues at GW and other larger schools would say that many of the junior faculty are quite adequate and capable at being instructors, but it is quite clear too that many of us who have come through the Ph.D. system realize that other than those who have majored in education, we are not primarily trained as educators, but trained as researchers. You acquire the ability to teach by trial and error, or through the years in a faculty position.

Mr. Nagle. Let me ask a question, my rule is when I don't know, I ask. It's a bad question and I apologize. You mentioned, Dr. Cole, about people who were going to become Ph.D.s. Is it necessary that our faculty be Ph.D.s in order to teach undergraduate science? Do you have to have a doctorate?

Dr. Cole. It is preferable. It is not necessary. Some of the finest teachers I have ever had have been people who did not have Ph.D.s. But we are talking about a level of experience that goes beyond just the ability to communicate facts and figures. We talk about the importance of the discipline that is traditionally involved in the training of scientists and engineers, and that that has to be passed on to the next generation and be improved upon.

So it is an important part of the basic training we expect to have at the undergraduate and graduate levels.

Now, it's a whole different question when you talk about high school. Because the problem is very serious there, across the board, not just in science and engineering. But we are not producing enough minority teachers for the public school system as well. And that's another function of the undergraduate experience.

Mr. Nagle. But is the focus of the curriculum, once you start down the science or math major path, that you are automatically going to be expected to pursue a Ph.D.? Are we setting out a seven-year road or a ten-year road? I like Ph.D.s, I have nothing against Ph.D.s. Some of my best friends are Ph.D.s. [Laughter.]

But I would like a few more M.As. walking around, too.

Dr. O'Brien. It is certainly not an expectation at the two liberal arts institutions I have been at. I think the primary purpose is educating in the sciences for the defined career goal that an individual has. One of the interesting things about obtaining a Ph.D., as I'm sure everybody would agree, once you get there you realize, "Gee, is this it?"

It is not the degree that gives the brains or the creativity. It is the process you have been through, the means to the end. It creates the understanding of science.

I believe it was Mike Doyle who mentioned earlier the failure in science. It is critical to understand what it means to fail, and perhaps fail over a period of months or years to really understand what scientific research is, which is the nuts and bolts of what we understand to be taught in a classroom as science fact.

So in the sciences, I would say for the undergraduate level, a Ph.D. is very preferable because of understanding the process of creativity.

Dr. **Stokes**. Another point, Congressman, is that at least in the large institutions, and probably in the small institutions, a comment was made earlier that students at the undergraduate level decide in terms of their careers. In actuality, the decision is made prior to their undergraduate years. We are talking about high school and elementary education level.

Students who lack the basic preparation are almost earmarked to go into programs or curricula at the undergraduate level which divert them from scientific careers. Those who lack the experience in science and math at the high school level and junior high schools are almost automatically self-selected out of science, even people who have the potential.

So the National Science Foundation and others should really take a hard look at not only undergraduate but prior to that, the elementary level, especially in terms of women and minorities.

Mr. **Nagle**. The statistical dropout, students who express interest by the eighth grade, is just staggering. I want to take one other track for the record, because Mr. Wolpe and I want to know, because I have raised these questions before, but a major problem with minority colleges and universities seems to be financial.

A witness on the first panel suggested that a matching funds requirement for the Instrumentation and Laboratory Improvement program be decreased from 50 percent to 35 percent. Do you have a response or reaction to that? Is that a direction we should consider?

Dr. **Gentile**. I would like to make one comment on that. I think that would be fine, as long as that program were increased in funding so that we didn't actually wind up spending more NSF funds on fewer grants.

Dr. **Cole**. Yes.

Mr. **Nagle**. I'm not a rocket scientist, but I figured that one out. [Laughter.]

Dr. **Gentile**. I thought it would be good to get it down somewhere on paper, though.

But I think in general that could be very beneficial to institutions in providing creativity. Right now it is very difficult to tell a young dynamic faculty member that we can't support a $100,000 match for an NSF grant, that we will have to wait a couple of years. That's really throwing cold water on someone, and it is very discouraging. So with that caveat, I think it would be a good approach.

Mr. **Nagle**. Dr. Cole? Dr. Stokes? Dr. O'Brien?

Dr. **Cole**. I would agree. Any movement in that direction certainly would be an incentive and would be of assistance to institutions. But let me just say that the notion of the matching fund requirement is a good principle. Because it does help leverage Federal dollars with non-Federal dollars, and I think that's a good practice. We have been able to take advantage of it.

Mr. **Nagle**. I would almost go further, though, I would almost have an offset on some of that, maybe 50 percent. I don't know if I wouldn't develop the criteria of cashworthiness of the institutions as to who has to do 50 percent or the 35 percent. I could get a little bit around the funding problem in that regard. I think we did that on a couple of undergraduate programs. But the other reactions to it—Dr. Stokes, Dr. O'Brien?

Dr. O'Brien. Certainly the requirement for matching funds selects against those institutions that do not have the ability to fund it through an operating budget. And I think for that reason I would favor decreasing from 50 percent to 35 percent. Again, I am concerned that the overall budget be increased to offset that.

Dr. Stokes. I would agree.

Mr. Nagle. Well, we're safe, he's back. Let me turn it back over to the chairman. I have enjoyed your testimony very much. But I have to tell you, I leave it disturbed. Because the thrust of what you are saying is, let's put the money where the ones that are doing the job are getting it done. And I agree with that.

But it is a bit disconcerting when you realize that in essence, we are looking at our larger universities and seeing that they are not doing the job. We don't really have an idea of how to get them to do the job under the current system. That is not your fault, but that is a disturbing trend.

Mr. Wolpe. Thank you very much, Mr. Nagle, for taking the chair. I'm terribly sorry I had to absent myself. I have of course read all the written testimony. This is excellent, and it is disturbing. But the good news is, of course, as was indicated by Dr. Cole, we know what needs to be done. The issue is trying to make it happen at this point, and putting the kinds of resources behind programs that do work at this juncture.

I understand you went through the questions that we as a committee wanted to be certain got asked for our record. I will not ask additional questions at this point. I do want to express my appreciation to all of you for your very important contributions. Thank you.

Mr. Nagle. Thank you.

Mr. Wolpe. I should alert people that we may have a vote shortly, but I want to at least get started with our third panel. I would like to invite Dr. Williams and Dr. Chubin to come to the witness table.

On our final panel, the first witness to testify will be Dr. Daryl Chubin, Senior Analyst and project Director for the Office of Technology Assessment's Division of Science Education and Transportation.

Dr. Chubin was project director for the well-respected 1988 OTA report entitled "Educating Scientists and Engineers from Grade School to Grad School." We have asked Dr. Chubin to compare the findings and recommendations of the Project Kaleidoscope report to those of the 1988 OTA report. We look forward to his analysis.

Our last witness in this hearing today will be Dr. Luther Williams. Dr. Williams is the Assistant Director of Education and Human Resources of the National Science Foundation. All the undergraduate programs at NSF that we have discussed today fall under Dr. Williams' purview. I am most interested in learning of NSF's reactions to the recommendations of Project Kaleidoscope and to the witnesses' comments that were made earlier today.

In addition, we would like to discuss with Dr. Williams the plans NSF has for taking concrete steps toward strengthening science education at the undergraduate level.

We will enable both of you to speak for a little more than the five-minute allocation, since we have a smaller panel at this stage. But again, we will ask you to summarize your remarks and your entire written testimony will of course be a part of the committee record.

At this point, I would like to ask if either of you have any objection to being sworn in.

[Witnesses sworn.]

Mr. WOLPE. Dr. Chubin, would you like to go first?

TESTIMONY OF DR. DARYL E. CHUBIN, SENIOR ANALYST, PROJECT DIRECTOR, SCIENCE EDUCATION AND TRANSPORTATION, OFFICE OF TECHNOLOGY ASSESSMENT

Dr. CHUBIN. Good afternoon.

Mr. Chairman, three years ago, OTA reported that "* * * liberal arts colleges are unusually productive of future Ph.D. scientists and engineers. Predominantly women's colleges and historically Black colleges and universities provide role models and supportive environments for smaller, more homogeneous populations. Like the research colleges, the value they place on teaching is reflected in the educational success and aspirations of their graduates."

While mathematics, science and engineering must be understood as "all one system", the role of undergraduate education in growing future research scientists cannot be overestimated. It is a time of significant talent loss and requires special attention. To increase participation in fields where groups have historically been underrepresented, policy intervention is required. Therefore, targeting certain segments of the student population and devising recruitment and retention programs are necessities.

Forward looking institutions of higher education, the "cultivators," recognized this long ago. They also found that what works for targeted populations seems to work for everyone. The key is converting the institutional leaders, those with traditionally high student attrition rates, into cultivators, by adjusting the learning environment.

Project Kaleidoscope is dedicated to mentor and peer support to promote educational achievement, in large part because NSF understands that human resources are a main business of the Federal Government.

The issue facing Congress, however, is not discovering "what works," but rather deciding how to invest scarce dollars in the dissemination and replication of what works. To this end, Congress seeks evidence of the effects of NSF programs on the recruitment and retention of students in technical majors.

Let me comment briefly on Project Kaleidoscope and then turn to NSF's role. Based solely on OTA's reading of Project Kaleidoscope's Volume 1 report, this NSF based project seems to have demonstrated what constitutes a supportive college culture. The institutions involved point the way to success. How to export this success to other institutions is now a challenge.

Project Kaleidoscope concerns a diversity of intervention models and shows how key ingredients of undergraduate science teaching and learning can take root in different institutional settings. The recommendations in Project Kaleidoscope's Volume 1 reflect a hearty appetite, including budget increases for NSF's education and human resources activities.

Thus, Project Kaleidoscope's call for an NSF facilities program to meet broad needs must reflect its belief in partnerships. Partnerships mean that institutions arrange to share the purchase and use of instrumentation and equipment, rather than fund such needs on each college campus. At minimum, a plan for sharing of infrastructure by ICO member institutions should be submitted to NSF to demonstrate how the partnerships created through Project Kaleidoscope would increase the utilization of facilities for instructional purposes.

Project Kaleidoscope is also about perseverance in crafting and implementing models to emulate, as well as generating the resources to sustain such models. Educational institutions need practical advice on replicating what works. These institutions are the primary audience for Project Kaleidoscope's results.

While Volume 1 presents a diversity of examples, the Independent Colleges Office should now focus on moving beyond descriptions of these and other ongoing Project Kaleidoscope experiments. We all need to know the pros and cons of running new programs based on new models.

Useful too in the Project Kaleidoscope volume yet to come would be some statistical information, provided at least for participating institutions featured in Volume 1, and outcomes relative to the four declared initiatives of Project Kaleidoscope.

What then should be NSF's role in supporting Project Kaleidoscope and similar projects? First, OTA believes that while Federal agencies can seed programs and showcase successes, they cannot dictate what educational institutions should value and reward. The Federal Government can at best be a catalyst in changing faculty approaches to pedagogy.

Second, NSF's research directorates and the research universities that form their primary clientele receive by far the largest amounts of funding and correspondingly have the largest research infrastructures. Unfortunately, these institutions have not readily shared resources with smaller schools. Without better cooperation among educational institutions in the nurturing of research scientists, Project Kaleidoscope's vision of "natural science communities" will be difficult to achieve.

Third, NSF must look at Project Kaleidoscope as well as its other programs intended to integrate education and research missions in terms of outcomes. This is not simply a matter of accountability. It is an opportunity for organizational learning and the transfer of those lessons. In an era of the President's and governors' national education goals, the FCCSET committee's *By The Year 2000* report, and the mounting clamor for K-12 standards, assessment and accountability, NSF should routinely collect and analyze information about the performance of programs it supports. This is an overriding part of educational oversight.

NSF should thus be prepared to respond to inquiries from Congress and others about changes due to their programs.

Finally, OTA applauds what NSF and the Education and Human Resources Directorate is seeking to accomplish in undergraduate science education. In closing, OTA would ask, is the Project Kaleidoscope model an NSF educational priority? Where does it fit along the panoply of education and human resources programs?

What would NSF suggest is the most constructive role Congress can play, aside—I emphasize the word aside—from the provision of more funds? And how would the fiscal year 1993 budget requests for instructional laboratory equipment and for course and curriculum development recommended by Project Kaleidoscope change if the total proposed increase for NSF were to be one half, or for that matter, twice that proposed for fiscal year 1992?

To put it another way, are these items such high priorities that they should be insulated from the vagaries of the budget?

Thank you, Mr. Chairman.

[The prepared statement of Dr. Chubin follows:]

How to Grow Research Scientists:
NSF and the Project Kaleidoscope Model

STATEMENT OF DR. DARYL E. CHUBIN
Senior Analyst
Office of Technology Assessment
Congress of the United States

Testimony Before the
Subcommittee on Investigations and Oversight
Committee on Science, Space, and Technology
U.S. House of Representatives

July 11, 1991

Three years ago in testimony before this Committee on the then-new OTA report, *Educating Scientists and Engineers: Grade School to Grad School*, we noted that:

> . . . liberal arts colleges . . . are unusually productive of future Ph.D. scientists and engineers. Predominantly women's colleges and historically Black colleges and universities provide role models and supportive environments for smaller, more homogeneous populations. Like the research colleges, the value they place on teaching is reflected in the educational success and aspirations of their graduates.[1] [See exhibit 1.]

If anything, the role of these undergraduate institutions has grown as contributors to the Nation's science and engineering work force. And the conclusions of OTA's 1988 analysis of "productive environments" (exhibit 2) remain valid today. **While mathematics, science, and engineering education must be understood as "all one system," the role of undergraduate education in growing future research scientists cannot be overemphasized.** Congress's current emphasis on the K-12 segment of the system tends to subordinate the college years as a critical transition, but it is a time of significant talent loss and requires special interventions. (For some students it is the *first* chance to experience science-as-process, "hands on" with a caring, often-inspiring faculty role model.) OTA's policy options -- then as now -- highlight attention to three vital areas for renewal and reform of the system: recruitment, retention, and the role of the Federal Government (exhibit 3).

The Federal Role

The National Science Foundation (NSF) has been the fount of Federal leadership in science education. Long before today's focus on the Independent Colleges Office (ICO) and Project Kaleidoscope (PKAL), or on the 1986 Neal Report,[2] NSF was a catalyst in spearheading a variety of innovative programs targeted to undergraduates.[3] The issue facing Congress is not discovering "what works," but rather deciding how to invest scarce dollars in the dissemination and replication of what works. To this end, Congress seeks evidence of the effects of NSF programs on the recruitment and retention of students in technical majors. NSF, which is asked to be all things to all scientists and to fulfill every mission related to mathematics, science, and engineering education and research, could surely do more with more resources. (No one knows this better than this Committee.) The question is how much to direct to what kinds of institutions and groups of students. The Education and Human Resources (EHR) Directorate should be able to guide Congress whenever questions about resources for a particular mission or program or project arise.

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[1] U.S. Congress, Office of Technology Assessment, *Educating Scientists and Engineers: Grade School to Grad School*, OTA-SET-377 (Washington, DC: U.S. Government Printing Office, June 1988), pp. 57-58.

[2] National Science Board, Task Committee on Undergraduate Science and Engineering Education, *Undergraduate Science, Mathematics and Engineering Education*, NSB 86-100 (Washington, DC: National Science Foundation, March 1986).

In the recent report, *Federally Funded Research: Decisions for a Decade*, OTA revisits the changing demographics of the student population, and examines the institutional underpinnings of recruitment and retention.[4] Indeed, OTA suggests that, in addition to scientific merit, a primary criterion for Federal investment in research should be ". . . strengthening education and human resources, e.g., increasing the number and diversity of participants. . ." in science and engineering careers.[5]

Years ago the National Science Board established as one of four criteria for the funding of research projects by NSF ". . . the effect of the research on the infrastructure of science and engineering . . . to contribute to better understanding or improvement of the quality, distribution, or effectiveness of the Nation's scientific and engineering research, education, and manpower base"[6]

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[3] For a full discussion, see U.S. Congress, Office of Technology Assessment, *Higher Education for Science and Engineering*, OTA-BP-SET-52 (Washington, DC: March 1989), ch. 2, especially table 2-12.

[4] OTA writes: "Concerns about the demographics of Ph.D. recipients could also be addressed. Laws that prohibit discrimination, such as Title VI of the Civil Rights Act of 1964 and Title IX of the Education Amendments of 1972, justify support to groups defined by the ascribed characteristics of race/ethnicity and sex, respectively. The 1980 reauthorization of the National Science Foundation also created the Science and Technology Equal Opportunities Act (Public Law 96-516)." See U.S. Congress, Office of Technology Assessment, *Federally Funded Research: Decisions for a Decade*, OTA-SET-490 (Washington, DC: U.S. Government Printing Office, May 1991), pp. 216-217.

[5] Ibid., p. 16.

[6] National Science Foundation, *Grants for Research and Education in Science and Engineering: An Application Guide*, NSF 90-77 (Washington, DC: August 1990), pp. 8-9.

(exhibit 4). Today, debate over reauthorization of the Higher Education Act reminds us again that legislation directs the research agencies to enhance the participation of minorities, women, and the physically disabled in science (for a review of landmark legislation, see exhibit 5).[7]

To increase the participation of these groups in fields where they have historically been underrepresented, policy intervention is required. **Therefore, targeting certain segments of the student population and devising recruitment and retention programs are necessities.** Forward-looking "cultivator" institutions work to help students develop as needed to stay in school and do well. They also found that what works for targeted populations, in the words of AAAS's Dr. Shirley Malcom, ". . . seems to work for everyone." The key is converting the institutional "weeders" -- universities with traditionally high rates of student attrition -- into cultivators. This begins by adjusting the learning environment -- providing mentor and peer support -- to curb student attrition and promote educational achievement. Project Kaleidoscope is dedicated to these adjustments in large part because NSF understands that human resources are a main business of the Federal Government.[8]

Looking Ahead: Questions for NSF

NSF must look at PKAL, as well as its other programs intended to integrate education and research missions, in terms of outcomes. **What is the evidence -- and the most compelling measures -- of program success? How are outcomes (as well as process) evaluated, especially by co-sponsoring organizations? This is not simply a matter of accountability; it is an opportunity for organizational learning and the transfer of those lessons.**

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[7] For example, it was noted at a recent hearing before the House Subcommittee on Postsecondary Education that the Federal Government spends more on "early intervention" techniques to encourage "at-risk" students to graduate from high school and continue their educations in college. Lacking information on admissions and financial aid, as well as psychological and emotional support at home and school, many disadvantaged and minority students entertain no such prospects. See "Colleges Call for More Federal Spending on 'At Risk' Students," *The Chronicle of Higher Education*, May 22, 1991, p. A21.

[8] Every *research* program at NSF -- not just the activities in the Education and Human Resources Directorate -- now impacts on human resources for science and engineering. This is clearly reflected in the proliferation of "set aside" programs at NSF; such programs categorically define the eligible pool of competitors for research funding, e.g., by professional age, gender, race and ethnicity, or geography. See U.S. Congress, Office of Technology Assessment, *Federally Funded Research*, op.cit., footnote 4, especially ch. 7.

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A. Gauging outcomes requires benchmarks of progress toward stated goals. The Howard Hughes Medical Institute, for example, is currently constructing measures of their educational programs' impacts. As encouraged as OTA may be about the soundness of the PKAL approach, how do educators and policymakers – *and NSF* – know that this project is making a difference? In an era of the President's and Governors' national education goals, the Office of Science and Technology Policy's Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) Committee's *By the Year 2000* report, and the mounting clamor for standards, assessment, and accountability at grades 4, 8, and 12, NSF should routinely collect and analyze information about the performance of programs it supports. NSF program managers should know what is happening on a real-time basis, and be able to inform Congress. This is a fundamental aspect of educational oversight.

B. NSF, and particularly the EHR Directorate, should also be prepared to respond – often and with candor – about changes *due to their programs*. How these changes are demonstrated or measured, e.g., in student choice, persistence, or performance, or in faculty course offerings and institutional rewards, is for NSF to decide and Congress to monitor.

Project Kaleidoscope

Based solely on the reading of Project Kaleidoscope's Volume I report, this NSF-based project seems to have demonstrated what constitutes a rewarding college culture. The institutions involved in PKAL projects point the way to success in those efforts. How to export this success to other institutions is now a primary challenge. Project Kaleidoscope concerns a diversity of intervention models and shows how key ingredients of undergraduate science teaching and learning can take root in different institutional settings. What are the ingredients and PKAL's current and planned use of them?

A. Partnerships -- a sharing of faculty and infrastructure -- are a cornerstone of PKAL. Partnerships mean that institutions arrange to share the purchase and use of instrumentation and equipment, or the construction of research facilities, rather than fund such needs on *each* college campus. Partnerships mean finding a way to combine private and nonprofit support to underwrite the infrastructure needs of clustered institutions. Cooperative research and teaching in science today must become inter-institutional. This, OTA believes, is a hard reality of research and higher education in the 1990s.

Another reality is that NSF's research directorates and the research universities that form their primary clientele receive by far the largest amounts of funding and, correspondingly, have the largest research infrastructures. Unfortunately, these institutions have not readily shared resources with smaller schools. Without better cooperation and a more nearly seamless web of relations among educational institutions in the nurturance of research scientists, the Project Kaleidoscope vision of "natural science communities" will be difficult to achieve.

B. The recommendations in PKAL's Volume I reflect a hearty appetite: budget increases for NSF's Education and Human Resources activities, expansion of the Research Experiences for Undergraduates program, strengthening of pre- and in-service activities for K-12 teachers, opportunities for national and regional colloquia to discuss what works, and dialogue about a super computer highway to link undergraduate math and science faculty to one another and their precollege counterparts.

The Federal Government has begun to "seed" programs and showcase successes. It cannot dictate, however, what educational institutions should value and reward. The Federal Government can at best be a catalyst in changing faculty approaches to pedagogy, and this is where partnerships and local educational leadership must come into play.

C. Project Kaleidoscope is about perseverence in crafting and implementing models to emulate, as well as generating the resources to sustain such communities. Contrast this with research reports: we know what works in math and science education, and we know that liberal arts colleges and predominantly undergraduate institutions are the chief venues for what works *best*. Educational institutions need practical advice on replicating what works. These institutions are the primary audience for PKAL results, not NSF or Federal policymakers. Volume I presents a diversity of examples: geology at Hamilton College, biology at Morehouse and the Atlanta University Center, the American Chemical Society's collaborative "chemistry in context" project, etc. ICO should now focus on moving beyond descriptions in reporting the experience of these and other ongoing PKAL experiments.[9] We all need to know the practical pros and cons of running real programs based on "what works" models.

What would be most useful in the Project Kaleidoscope volume yet to come is some statistical information, provided at least for participating institutions featured in volume I, on outcomes relative to the four declared initiatives of PKAL -- reforming course content, supporting the integration of the teacher-scholar role, educating K-12 teachers in math and science, and developing partnerships. What measures of progress toward these goals are being used in PKAL and by NSF's Division of Undergraduate Science, Engineering, and Mathematics Education? How do these measures relate to FCCSET Committee goals that cross all executive agencies? What is the timetable for achieving the declared milestones?

D. Insofar as the facilities needs for undergraduate science education envisioned in volume I are concerned, OTA believes that policymakers face tough choices in the allocation of scarce Federal dollars. These choices are often stark categories of what OTA calls competing "goods": buildings or people, teaching or research, universities or colleges. The tensions in the Federal research system pose daunting issues for Congress to debate in the budget process (exhibit 6).

Thus, PKAL's call for an NSF facilities program to meet broad needs must reflect its belief in partnerships. **At minimum, a plan for sharing by ICO member institutions the facilities modernized under any NSF program should be submitted to NSF to demonstrate how the partnerships created through PKAL would increase the utilization of facilities for instructional** purposes. But a large Federal facilities program could have major short- and long-term repercussions on the availability of research monies and the performance of research in academia (exhibit 7).[10]

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[9] For descriptions, see Project Kaleidoscope, *What Works: Building Natural Science Communities*, vol. I (Washington, DC: Independent Colleges Office, 1991).

OTA applauds what NSF and the Education and Human Resources Directorate is seeking to accomplish in undergraduate science education. Project Kaleidoscope is a promising model of how to grow research scientists at a key juncture of the pipeline. In closing, OTA would ask:

- Is the PKAL model an NSF educational priority?
- What would NSF suggest as the most constructive roles that Congress can play, aside from the provision of more funds?
- And how would the recommended fiscal year 1993 budget requests for instructional laboratory equipment and for course and curriculum development change if the total proposed increase for NSF were to be *one-half* or *twice* that proposed for fiscal year 1992? (Or are these such high priorities that they should be insulated from budget vagaries?)

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[10] PKAL's claim that a facilities program would eliminate "pork barrel decisions" is unfounded. NSF's merit review process cannot eliminate academic earmarking. These are separate issues united only by their appearance at different stages of the annual authorization and appropriations process. See Office of Technology Assessment, *Federally Funded Research*, op. cit., footnote 4, pp. 87-94.

Exhibit 1

Appendix A

Alphabetical Listing of Leading Undergraduate Sources of Science and Engineering Ph.D.s in Two Institutional Categories, 1950-75

The following alphabetical lists are based on an OTA analysis of the colleges and universities granting baccalaureate degrees to students who went on to earn a Ph.D. in science or engineering. Because large degree-granting institutions would be favored in a ranking based on the absolute number of baccalaureates produced that go on to earn Ph.D.s in science and engineering, OTA measured the contributions of baccalaureate-granting institutions to Ph.D. production, controlling for size of the institution.[1]

The 100 Most Productive Institutions

This category lists alphabetically the 100 institutions of all types with the highest ratios of baccalaureate degrees awarded (in all fields) to students who later earned science or engineering Ph.D.s (at any institution).[2]

Amherst College/MA
Antioch College/OH
Bard College/NY
Bates College/ME
Beloit College/WI
Berea College/KY
Blackburn College/IL
Bowdoin College/ME
Brandeis University/MA
Brown University/RI
Bryn Mawr College/PA
Bucknell University/PA
California Institute of Technology
Carleton College/MN
Carnegie-Mellon University/PA
Case Western Reserve University/OH
Centre College of Kentucky
City University of New York
Clark University/MA
College of Charleston/SC
College of Wooster/OH
Colorado School of Mines
Columbia University/NY
Cooper Union/NY
Cornell University/NY
Dartmouth College/NH
Davidson College/NC
Delaware Valley College/PA
Drew University/NJ
Duke University/NC
Earlham College/IN
Eckerd College/FL
Franklin and Marshall College/PA
Grinnell College/IA
Hamilton College/NY
Hampshire College/MA
Harvard University/MA
Harvey Mudd College/CA
Haverford College/PA
Hope College/MI
Illinois Benedictine College
Illinois Institute of Technology
Iowa State University
The Johns Hopkins University/MD
Juniata College/PA
Kalamazoo College/MI
Kenyon College/OH
King College/TN
Knox College/IL
Lafayette College/PA

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[1] Betty D. Maxfield, "Institutional Productivity: The Undergraduate Origins of Science and Engineering Ph.D.s," OTA contractor report, July 1987. Baccalaureates awarded are based on the Department of Education's National Center for Statistics institutional counts, reported in *Earned Degrees Conferred*. Six academic years were sampled in this analysis for baccalaureate data: 1950, 1955, 1960, 1965, 1970, and 1975. All baccalaureate information was matched (through 1986) with Ph.D. data from the National Research Council's Doctorate Records File, which is based on annual Surveys of Earned Doctorates. New Ph.D. recipients, in cooperation with their institutions' graduate studies offices, complete questionnaires that provide basic demographic, educational, and planned employment characteristics. This information is the basis of the Ph.D. counts used in calculating the institutional ratios of science and engineering Ph.D.s per 100 baccalaureates.

[2] These 100 include the 15 "technical" institutions (that emphasize science or engineering) whose productivity was shown separately in figure 3-4. The ratio of science and engineering Ph.D.s earned per 100 baccalaureate degrees awarded by these institutions range from 4 to 44.

SOURCE: U.S. Congress, Office of Technology Assessment, Educating Scientists and Engineers: Grade School to Grad School, OTA-SET-377 (Washington, DC: U.S. Government Printing Office, June 1988).

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Exhibit 1 (cont.)

Lawrence University/WI
Lebanon Valley College/PA
Lehigh University/PA
Macalester College/MN
Massachusetts Institute of Technology
Muhlenberg College/PA
New Mexico Institute of Mining and Technology
Oberlin College/OH
Occidental College/CA
Philadelphia College of Pharmacy and Science/PA
Pitzer College/CA
Polytechnic University/NY
Pomona College/CA
Princeton University/NJ
Radcliffe College/MA
Reed College/OR
Rensselaer Polytechnic Institute/NY
Rhodes College/TN
Rice University/TX
South Dakota School of Mining and Technology
Stanford University/CA
State University of New York at Binghamton
State University of New York, College of
  Environmental Science and Forestry
State University of New York at Stony Brook
Stevens Institute of Technology/NJ
St. Johns College/MD
Swarthmore College/PA
Union University/NY
United States Merchant Marine Academy/NY
United States Military Academy/NY
University of California at Berkeley
University of California at Davis
University of California at Irvine
University of California at Los Angeles
University of California at Riverside
University of California at San Diego
University of California at Santa Cruz
University of Chicago/IL
University of Rochester/NY
University of South Florida, New College
Vassar College/NY
Wabash College/IN
Webb Institute of Naval Architecture/NY
Wellesley College/MA
Wesleyan University/CT
Whitman College/WA
Williams College/MA
Worcester Polytechnic Institute/MA
Yale University/CT
Yeshiva University/NY

49 Liberal Arts Colleges

The 50 liberal arts colleges that participated in the Second National Conference on "The Future of Science at Liberal Arts Colleges" at Oberlin College in June 1986 defined this list (presented alphabetically).[1]

Albion College/MI
Alma College/MI
Amherst College/MA
Antioch College/OH
Bates College/ME
Beloit College/WI
Bowdoin College/ME
Bryn Mawr College/PA
Bucknell University/PA
Carleton College/MN
Colgate University/NY
College of the Holy Cross/MA
College of Wooster/OH
Colorado College
Davidson College/NC
Denison University/OH
Depauw University/IN
Earlham College/PA
Franklin and Marshall College/PA
Grinnell College/IA
Hamilton College/NY
Hampton University/VA
Harvey Mudd College/CA
Haverford College/PA
Hope College/MI
Kalamazoo College/MI
Kenyon College/OH
Lafayette College/PA
Macalester College/MN
Manhattan College/NY
Middlebury College/VT
Mt. Holyoke College/MA
Oberlin College/OH
Occidental College/CA
Ohio Wesleyan University
Pomona College/CA
Reed College/OR
Smith College/MA

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[1] However, Barnard College's baccalaureate counts were not reported separately from Columbia University. Thus, the 50 private liberal arts colleges, sometimes referred to as "research colleges" because of their emphasis on undergraduate and faculty research, were reduced to 49. The ratios of science and engineering Ph.D.s earned per 100 baccalaureates awarded by these institutions vary from 1 to 30.

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Exhibit 1 (cont.)

St. Olaf College/MN
Swarthmore College/PA
Trinity College/CT
Union University/NY
Vassar College/NY
Wabash College/IN
Wellesley College/MA
Wesleyan University/CT
Wheaton College/IL
Whitman College/WA
Williams College/MA

EXHIBIT 2

PRODUCTIVE ENVIRONMENTS—UNDERGRADUATE ORIGINS OF SCIENTISTS AND ENGINEERS

Variety among higher education institutions distinguishes the United States from other countries and contributes enormously to the education system's success and ability to reach so many students. Institutions include vast State universities and colleges (obliged to admit qualified resident high school graduates), engineering institutes akin to industrial training schools, and research universities of international repute. Private liberal arts colleges, historically Black institutions, and an array of others complete the picture.

Each type of institution serves a different clientele and has a particular local, State, or national

SOURCE: U.S. Congress, Office of Technology Assessment, Educating Scientists and Engineers: Grade School to Grad School, OTA-SET-377 (Washington, DC: U.S. Government Printing Office, June 1988), pp. 56-58.

Exhibit 2 (cont.)

context. Community colleges, predominantly county-based, train skilled workers and serve, for a few, as stepping stones to full baccalaureate programs. Liberal arts colleges are rooted in the classical notion that exposure to the great books and works in all disciplines is the way to instill democracy and higher-order thinking in the citizenry.

Institutions also vary in their relative emphasis on teaching and research, and on undergraduate and graduate teaching. One group of institutions, research universities, specializes in research and graduate teaching. Another group, a subset of the liberal arts colleges, specializes in undergraduate education, but does research as well. Some institutions are oriented primarily or exclusively to certain populations such as Blacks or women. Each type of institution, with its unique role, contributes to the strength of the entire higher education system.

There is competition among types of institutions and within the types themselves. Institutions compete for Federal and industry research funds, for talented students and faculty, and for equipment and facilities support. Most science and engineering undergraduates are produced by the major research universities, State institutions, and the private liberal arts colleges. From the point of view of the future science and engineering research work force, an important measure of the success of the education provided by these environments is the number of their graduates that go on to earn Ph.D.s in science and engineering.

Graduates who later earn Ph.D.s in science and engineering come from a limited number of undergraduate institutions. Ranked by the absolute number of their alumni that later receive Ph.D.s in science and engineering, 100 schools supply 40 percent of all students who receive doctorates. Four out of five of these top 100 undergraduate institutions are private.[28] Of these institutions, large degree-granting institutions (the "research universities") have the highest output of bachelor's graduates who go on to earn science and engineering Ph.D.s.

A group of about 50 private liberal arts colleges, however, has claimed to be especially productive, and accordingly, deserving of funding for research equipment and teaching.[29] These "research colleges" claim that their traditional small scale, emphasis on research experiences for undergraduates, and focus on individual students are major contributors to the eventual production of Ph.D.s in science and engineering.[30] For example, their students are encouraged to work with faculty members on current scientific research and to become full participants in research teams. A subset of this group, such as Bryn Mawr, Mt. Holyoke, and Smith, focuses on educating women and claims to be particularly productive of female scientists.

By looking at an estimate of the proportion of each institution's baccalaureate graduates in all fields that have gone on to gain Ph.D.s in science and engineering, OTA finds that some liberal arts colleges as well as universities that specialize in technical education are unusually productive of future Ph.D. scientists and engineers, when allowance is made for the size of these colleges (see figure 3-6). A large proportion of the graduates of these environments also subsequently join the research work force.[31]

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[28] This finding is based on an analysis of four baccalaureate cohorts dating from academic years 1950-51 to 1965-66. Degree totals were extracted from the Center for Education Statistics' annual *Earned Degrees Conferred*, and linked to the National Research Council's Doctorate Records File to calculate institutional productivity rankings through 1979. A 10-year lag from baccalaureate to Ph.D. award was used to create this indicator of institutional productivity. The methodology and various rankings are contained in Betty Maxfield, "Persistence in Higher Science and Engineering (S/E) Education: S/E Baccalaureate to S/E Doctorate Productivity of U.S. Baccalaureate-Granting Institutions," OTA contractor report, September 1987.

[29] In 1985, these colleges undertook a self-study: David Davis-Van Atta et al., *Educating American Scientists: The Role of the Research College* (Oberlin, OH: Oberlin College, May 1985). A Second National Conference on "The Future of Science at Liberal Arts Colleges" in 1986 resulted in another report: Sam C. Carrier and David Davis-Van Atta, *Maintaining America's Scientific Productivity: The Necessity of the Liberal Arts Colleges* (Oberlin, OH: Oberlin College, March 1987). Together, they are known as the Oberlin Reports. Although the labels "research colleges" and "science intensives" have been applied, they are not embraced even by members of the 50 colleges. Also, another 50 colleges probably share the characteristics of those included in the Oberlin Reports (see app. A). Thus, OTA's use of the term "research colleges" refers to about 100 private liberal arts colleges where, historically (and ironically), teaching has been especially valued.

[30] A quarter-century ago, liberal arts colleges were found to be among the 50 most productive institutions of higher education. R.H. Knapp and H.B. Goodrich, "The Origin of American Scientists," *Science*, vol. 133, May 1951, pp. 543-545. This finding was later confirmed by M.E. Tidball and V. Kistiakowsky, "Baccalaureate Origins of American Scientists and Scholars," *Science*, vol. 193, August 1976, pp. 646-652.

[31] During the 1970s, when single-sex colleges either merged or began admitting sizable numbers of students of the opposite sex, 2 percent of women baccalaureates from coeducational institutions went on for a science or engineering Ph.D. compared to 10 percent of the graduates of women's colleges. See M.E. Tidball, "Baccalaureate Origins of

(continued on next page)

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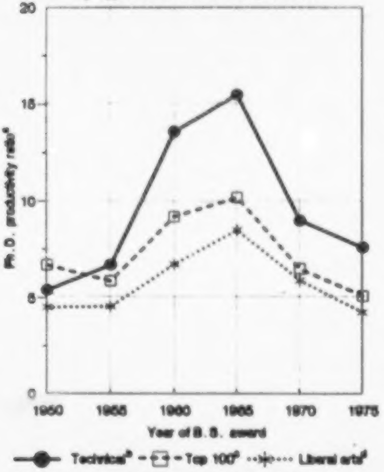
Exhibit 2 (cont.)

Figure 3-6.—Science/Engineering Ph.D. Productivity, by Type of B.S. Institution, 1950-75



[a]Percent of all B.S. graduates who later get science/engineering Ph.D.s. The bulge in science/engineering Ph.D. productivity tracks the increase in Federal fellowship (and R&D) spending during the 1960s.

[b]Fifteen institutions with an emphasis on science/engineering and that send a large proportion of their students on to science/engineering Ph.D.s.

[c]The 100 institutions of all types that have the highest productivity ratios for science/engineering Ph.D.s.

[d]The 50 liberal arts colleges that participated in the Second National Conference on "The Future of Science at Liberal Arts Colleges" at Oberlin, June 1985. These colleges are also known as "research colleges" due to their emphasis on undergraduate and faculty research.

SOURCE: Betty D. Maxfield, OTA contractor report, 1987.

Figure 3-6 also reveals a peak in the 1960s that can be traced (see below) to the sharp rise in Federal fellowship and academic research funding in the early 1960s, followed by decline from the late 1960s into the 1970s. The bulge in baccalaureates going on for science and engineering Ph.D.s appears in all types of institutions, but is pronounced in the research-oriented ones and those receiving the most Federal dollars.

The quality of students recruited and enrolled in an institution, of course, is related to the number and quality of those who emerge with baccalaureate degrees. The education provided by the research colleges is very costly; most of the costs are borne by students and their families.[32] These colleges are highly selective in admitting students, but make great efforts to ensure students' success by offering considerable personal attention and support. The institutional environment clearly matters.[33] Elements of students' experiences in the research colleges that encourage pursuit of the Ph.D., such as early research experience, the emphasis that such schools place on teaching, and their small student-faculty ratios, could be replicated at other institutions.[34] **OTA concludes that to increase numbers of Ph.D. scientists and engineers, it would be worth studying techniques used by research colleges and encourage other institutions to adopt similar strategies and values.**

(continued from previous page)
Recent Natural Science Doctorates," *Journal of Higher Education*, vol. 57, No. 6, November/December 1986, pp. 606-620. In the analysis reported here, total baccalaureate output, not numbers of males and females separately, defined the productivity of institutions. Except for the predominantly women's colleges, OTA has not determined which institutions sent large numbers of women on for Ph.D.s; only the top Ph.D. producers for both sexes combined have been identified. (Elisabeth Tidball, personal communication, Dec. 16, 1987.) Also note that the predominantly women's colleges and historically Black colleges and universities serve more homogeneous populations than other types of institutions. Numerical comparisons with coeducational, largely white institutions do not capture this special kind of productivity. See, for example, Michael T. Nettles et al., "Comparative and Predictive Analyses of Black and White Students' College Achievement and Experiences," *Journal of Higher Education*, vol. 57, No. 3, May-June 1986, pp. 289-318. Institutional-level measurement is at best a crude proxy for the climate that fosters educational success of those who experience it, and perhaps contributes to students' later persistence to the Ph.D.

[32]Carrier and Davis-Van Atta, op. cit., footnote 29.

[33]Robert S. Eckley, "Liberal Arts Colleges: Can They Compete?" *The Brookings Review*, vol. 4, No. 4, fall 1987, pp. 31-37. Not only is there lack of agreement on the definition of and criteria for measuring student "quality," but ". . . there are no detailed and comparable national data on student performance at the postsecondary level. At best, only crude estimates can be made of the quality of subgroups in the graduate talent pool by examining trends and characteristics of the applicants taking such tests as the GRE [Graduate Record Examination]." Brown, op. cit., footnote 24, p. 7. Also see T.W. Hartle, "The Growing Interest in Measuring the Educational Achievement of College Students," *Assessment in American Higher Education*, C. Adelman (ed.) (Washington, DC: U.S. Department of Education, 1986).

[34]Alexander W. Astin, *Four Critical Years* (San Francisco, CA: Jossey-Bass, 1977), esp. pp. 44, 89. These elements are central to some other highly productive (small technical) institutions such as Harvey Mudd and the California Institute of Technology. Like the Massachusetts Institute of Technology and other research universities, these institutions emphasize undergraduate research, indeed often require a research thesis for graduation. See, for example, Janet Lansa, "Whys and Hows of Undergraduate Research," *BioScience*, vol. 38, No. 2, February 1988, pp. 110-112.

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Exhibit 3

Policy Options to Improve Science and Engineering Education

Recruitment—Enlarge the Pool

- *Elementary and secondary teaching:* encourage and reward teachers; expand support for preservice and inservice training.
- *School opportunities:* reproduce science-intensive schools, adjust course-taking and curricula, review tracking, and revise testing.
- *Intervention programs:* increase interest in and readiness for science and engineering majors; transfer the lessons from successful programs; encourage sponsorship from all sources.
- *Informal education:* increase support of science centers, TV, fairs, and camps.
- *Opportunities for women:* enforce Title IX of the Education Amendments of 1972 and provide special support and intervention.
- *Opportunities for minorities:* enforce civil rights legislation and provide special support and intervention.

Retention—Keep Students in the Pool

- *Graduate training support:* "buy" Ph.D.s with fellowships and traineeships; these people are most likely to join the research work force.
- *Academic R&D spending:* bolster demand and support research assistants, especially through the mission agencies.
- *Foreign students:* adjust immigration policy to ease entry and retention.
- *Undergraduate environments:* support institutions that reward teaching and provide role models, such as research colleges and universities, and historically Black institutions.
- *Hands-on experience:* encourage undergraduate research apprenticeships and cooperative education that impart career skills.
- *Targeted support for undergraduates:* link need- or merit-based aid to college major.

Strengthen Federal Science and Engineering Education Efforts

- *National Science Foundation as lead science education agency:* underscore responsibility through the Science and Engineering Education Directorate for elementary through undergraduate science programs.
- *Federal interagency coordination and data collection:* raise the visibility of science education and the transfer of information between agencies and to educational communities.

SOURCE: U.S. Congress, Office of Technology Assessment, Educating Scientists and Engineers: Grade School to Grad School, OTA-SET-377 (Washington, DC: U.S. Government Printing Office, June 1988).

Exhibit 4

Box 1-B—Criteria for Research Decisionmaking in Agency Programs

Within agency research programs, research proposals have traditionally been selected for support on the basis of expert peer or program manager judgments of "scientific merit" and program relevance. Many Federal agencies are now finding that the introduction of other explicit criteria is important for research decisionmaking.[1]

For example, the National Science Board (NSB) established the following criteria for the selection of research projects by the National Science Foundation (NSF): 1) research performer competence, 2) intrinsic merit of the research, and 3) utility or relevance of the research. In addition, NSB included 4) the ". . . effect of the research on the infrastructure of science and engineering. This criterion relates to the potential of the proposed research to contribute to better understanding or improvement of the quality, distribution, or effectiveness of the Nation's scientific and engineering research, education, and manpower base."[2]

Under this fourth criterion, NSF includes:

[illegible] science, engineering, and education; [illegible] including participation of women, minorities, and disabled [illegible] the distribution of resources with respect to institutions and geographical area; stimulation of high quality activities in important but underdeveloped fields; support of research initiation for investigators without prior Federal research support as a Principal Investigator or Co-Principal Investigator; and [illegible] to research or education in appropriate areas.[3]

In short, this criterion creates the basis for using other criteria in addition to scientific merit in mainstream allocations of research funds, and within set-aside programs. Set-aside programs, at NSF and elsewhere, underscore the continuing need for "sheltered competitions" for researchers who do not fare well in mainstream disciplinary programs.[4]

As acknowledged by NSB, although scientific merit and program relevance must always be the primary criteria used to judge a research program or project's potential worth, they cannot always be the only criteria. For most of today's research programs, there are many more scientifically meritorious projects than can be funded. Proposal

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[1] OTA interviews, spring-summer 1990.

[2] Quoted in National Science Foundation, *Grants for Research and Education in Science and Engineering: An Application Guide*, NSF 90-77 (Washington, DC: August 1990), pp. 8-9.

[3] Ibid., p.9.

[4] OTA finds that, in some programs at the National Science Foundation (NSF), the fourth criterion is not strongly heeded relative to the other three criteria in the merit review process (OTA interviews, spring-summer, 1990). NSF faces the impossible task of being all things to all people. The organic act entrusts it with the support of the Nation's basic research and science education. In the academic institutions that form NSF's core clientele these activities are not pursued in the same way or with the same vigor. Every research program at NSF now impacts on human resources for science and engineering. This should remain foremost in mind when weighing policies for research programs.

SOURCE: U.S. Congress, Office of Technology Assessment, Federally Funded Research: Decisions for a Decade, OTA-SET-490 (Washington, DC: U.S. Government Printing Office, May 1991).

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Exhibit 4 (cont.)

review could thus be an iterative process. First, a pool of proposals could be identified based on scientific merit and program relevance, and those with exceptional human resources and/or research infrastructure potential so indicated. The program manager, with or without the advice of expert peers, can then pick a balanced subset from the pool. Any of several subsets might be equally meritorious—this is where selection criteria and judgment enter the process. The result is a program research portfolio that can be reshaped in succeeding years.

OTA suggests that two broad criteria could be applied to research project selection: strengthening education and human resources, and building regional and institutional capacity. How might these two additional criteria be rated in research proposals?

- *Education and human resources* criteria would weigh proposals on their future production of new researchers or technically skilled students. Outcome measures would relate to undergraduate education, graduate training, and characteristics of new Ph.D.s—the number and quality of those entering graduate study and the research work force, respectively.

  Contributions to human resources include increasing participation in the educational pipeline (through degree completion), the research work force, and the larger science and engineering work force. With the changing character of the student population, tapping the diversity of traditionally underrepresented groups in science and engineering (e.g., women and U.S. minorities) is vital for the long-term health of the research work force.
- *Regional and institutional capacity* criteria would weigh proposals on their contribution to underparticipating regions and institutions. Outcome measures would include the enhanced research competitiveness of funded institutions; State, local, and private participation in the support of the research infrastructure; and an enlarged role in training and employment in targeted sectors, industries, and fields.

  Regional and institutional capacity are important concerns in all Federal funding, reflecting the interests of taxpayers. While the major research universities are exemplary in their production of research, untapped resources could be developed in other types of educational institutions throughout the United States.[5]

Funding research to achieve all of these objectives will remain a prerogative of Congress. But decisions that add tomorrow's criteria to today's, especially in the review of project proposals at the research agencies, will expand the capability of the Federal research system.

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[5] If the Federal Government wishes to augment the economic health of a particular region, supporting research in that area is one means of achieving it. "Spin-offs" from research centers have traditionally improved local economies by encouraging development of technical industries and local research infrastructures. They also often contribute to local educational efforts and directly provide technical jobs for residents. See U.S. Congress, Office of Technology Assessment, *Higher Education for Science and Engineering*, OTA-TM-SET-52 (Washington, DC: U.S. Government Printing Office, March 1989).

Exhibit 5

Table 4-1.—Landmark Federal Legislation Affecting Science and Engineering Education

1862	**Morrill Act.** Established land grant colleges, and the precedent for Federal support of institutions of higher education.
1890	**Second Morrill Act.** Required States with dual systems of higher education to provide land grant institutions for Blacks as well as whites. Sixteen Black institutions were established as 1890 Land Grant colleges.
1937	**National Cancer Institute Act.** One of the first in a long line of health manpower/National Institutes of Health acts.
1944	**Serviceman's Readjustment Act (G.I. Bill).** Provided extensive Federal support for large numbers of new undergraduate and graduate students. Not targeted to science and engineering, but by increasing the number of college students increased the output of scientists and engineers. Nearly 8 million World War II veterans enrolled; many chose science and engineering majors.
1950	**National Science Foundation Act.** Established the National Science Foundation and included support of science education in the National Science Foundation's mission of supporting basic science. Set the tone for graduate science and engineering education: merit and geographical balance are the primary award criteria, with oversight of professional replenishment vested in the scientific community.
1951	**Selective Service Amendments of 1951.** Created draft deferrals for college students and for scientists. Following 1967, Act made students more vulnerable to the draft, and full-time graduate enrollment dropped as male students took deferrable full-time jobs.
1958	**National Defense Education Act.** Science and mathematics were major areas targeted for improvement through generous funding for equipment, guidance, testing, teacher training, and educational research. Increased the role of the Office of Education in science and engineering education. Authorized many graduate fellowships and undergraduate loans. The National Defense Education Act was expanded to most fields in 1964.
1964	**Civil Rights Act.** Title IV set up technical advice structure for elementary and secondary schools to desegregrate on the basis of sex, race, color, religion, or national origin. Title VII prohibited sex discrimination in employment (hiring, firing, pay, and working conditions).
1965	**Elementary and Secondary Education Act.** Established massive Federal support for schools and materials, particularly for schools with nontraditional and disadvantaged students. No focus on particular curricular area. Directed Federal education policy and money to special underserved populations (low-income, handicapped).
1965	**Higher Education Act.** First major Federal legislation for higher education not linked to a specific goal (e.g., national defense), but rather to promote equality of access, student freedom of choice, quality of education, and efficient use of human resources. Brought Federal money into higher education and expanded college enrollments. Supported continuing and cooperative education, libraries, teacher training, facilities, and student financial aid. Title II included a provision to support minority institutions.
1967-8	**Elementary and Secondary Education Amendments.** Authorized support of regional centers for education of handicapped, particularly deaf and blind. Supported bilingual education programs.
1972	**Education Amendments.** Consolidated higher education legislation prohibited sex discrimination in federally assisted education programs. Title IX prohibited sex bias in admission to vocational, professional, graduate, and public undergraduate institutions.
1974	**National Research Service Awards Act (National Institutes of Health).** Shifted emphasis of the National Institutes of Health training from growth to renewal and quality in a constrained budget. Set out the principle of requiring students to return services in exchange for support (not enforced). Instituted manpower planning. Fellowships by law must constitute 15 percent of the research training budget.
1980	**Science and Technology Equal Opportunities Act.** Promoted the full development and use of the scientific talent and technical skills of men and women of all ethnic, racial, and economic backgrounds. Directed a biennial report to assess opportunities and participation rates.
1984	**Education for Economic Security Act.** Targeted mathematics, science, computer learning, and foreign languages. Under this Act, the Department of Education provides modest funding, mostly on a formula basis, for: teacher training, magnet schools (designed for desegregation, but some with science and mathematics emphasis), and for improving mathematics and science education.
1986	**National Science, Engineering, and Mathematics Authorization Act of 1986.** Established a Task Force on Women, Minorities, and the Handicapped in Science and Technology in the Federal Government and in federally assisted research programs.

SOURCE: Office of Technology Assessment, 1988.

SOURCE: U.S. Congress, Office of Technology Assessment, Educating Scientists and Engineers: Grade School to Grad School, OTA-SET-377 (Washington, DC: U.S. Government Printing Office, June 1988).

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Exhibit 6

Table 1-1—Tensions in the Federal Research System

Centralization of Federal research planning	←→	Pluralistic, decentralized agencies
Concentrated excellence	←→	Regional and institutional development (to enlarge capacity)
"Market" forces to determine the shape of the system	←→	Political intervention (targeted by goal, agency, program, institution)
Continuity in funding of senior investigators	←→	Provisions for young investigators
Peer review-based allocation	←→	Other funding decision mechanisms (agency manager discretion, congressional earmarking)
Set-aside programs	←→	Mainstreaming criteria in addition to scientific merit (e.g., race/ethnicity, gender, principal investigator age, geographic region)
Conservatism in funding allocation	←→	Risk-taking
Perception of a "total research budget"	←→	Reality of disaggregated funding decisions
Dollars for facilities or training	←→	Dollars for research projects
Large-scale, multiyear, capital-intensive, high-cost, per-investigator initiatives	←→	Individual investigator and small-team, 1-5 year projects
Training more researchers and creating more competition for funds	←→	Training fewer researchers and easing competition for funds
Emulating mentors' career paths	←→	Encouraging a diversity of career paths
Relying on historic methods to build the research work force	←→	Broadening the participation of traditionally underrepresented groups

SOURCE: Office of Technology Assessment, 1991.

Table 1-3—Summary of Issues and Possible Congressional Responses

Issue	Possible congressional responses
Setting priorities for research	Hearings on crosscutting priorities and congressional designation of a body of the Federal Government to evaluate priority setting. Application of criteria to: a) promote education and human resources, b) build regional and institutional capacity in merit-based research decisionmaking, and c) balance little science and megaproject initiatives. Oversight of agency research programs that focuses on strategies to fulfill the above criteria, and on responses to priority setting.
Coping with changing expenditures for research	Encouragement of greater cost-accountability by the research agencies and research performers (especially for indirect costs, megaprojects, and other multiyear initiatives). Allowance for the agencies to pursue direct cost containment measures for specific items of research budgets and to evaluate the effectiveness of each measure.
Adapting education and human resources to meet future needs	Programs that focus investment on the educational pipeline at the K-12 and undergraduate levels. Attention to diversity in the human resource base for research, especially to the contributions of underparticipating groups. Incentives for adapting agency programs and proposal requirements to a changing model of research (where teams are larger, more specialized, and share research equipment and facilities).
Refining data collection and analysis to improve research decisionmaking	Funding to: a) augment within-agency data collection and analysis on the Federal research system, and b) increase use of research program evaluation at the research agencies. Encouragement of data presentation and interpretation for use in policymaking, e.g., employing indicators and other techniques that measure outcomes and progress toward stated objectives.

SOURCE: Office of Technology Assessment, 1991.

SOURCE: U.S. Congress, Office of Technology Assessment, *Federally Funded Research: Decisions for a Decade*, OTA-SET-490 (Washington, DC: U.S. Government Printing Office, May 1991).

Exhibit 7

Box 6-D—A Federal Research Facilities Program? Perspectives From Academia

In August 1990, University of Wisconsin at Madison Chancellor Donna E. Shalala wrote to President Bush urging development of a comprehensive plan to finance university research facilities. She stated:

> I recognize that there are a number of important competing claims on the Federal budget, even from the academic community. However, a planned Federal strategy at this stage can well save us money in the long run, and make more effective our other investments in science and engineering research and training.[1]

Even if money were appropriated to a Federal facilities program, there would be tough choices, such as an equal distribution of funds by category of institution or some weighted scheme that favors research-intensive universities.[2] Stanford's former Vice President for Finance, William E. Massy, outlines the following possible pitfalls:[3]

> What would happen if research sponsors were to shoulder the load of paying for needed university science facilities? . . . Research sponsors might adopt the "pay-now" strategy and provide the needed $5.85 billion up front. Congress is considering a facilities grant program, but it is hard to believe that anything like this amount could be provided over a few years without huge inroads on operating funds for research.
>
> On the other hand, if the "pay-later" strategy were adopted by sponsors, institutions would have to come up with up-front money on their own and then try to recover it through the overhead rate. This could be done in one of two ways: 1. Use gifts, institutional funds, or State appropriations. . . .[4] 2. Use debt. . . .
>
> Providing direct grants for facilities is an attractive option on its face, but . . . amounts would probably be modest in relation to need because of the [Federal] deficit. There is a real danger that appropriations would be at the expense of operating funds for science. . . . One reason for favoring a grant program is that it makes facilities available to institutions that are unable to provide up-front funding. . . . But it is precisely the institutions that have not yet been successful in merit-reviewed scientific competition that have the most need for a facilities grant program and would benefit most from it. . . .
>
> Facilities funding on a "pay-as-you-go" basis through the indirect cost rates puts the burden . . . on the institutions, and then reimburses them for some or all of the present value of these outlays. . . . Indirect cost rates would rise, . . . [and] institutions would have to bear the risks that a facility, once constructed, could not be filled with sponsored research at full overhead recovery. (The Federal Government takes that risk in an up-front grant program.) . . .
>
> While the Federal Government would be unlikely to announce a "won't pay" policy, that could happen by default if deficit reduction, "no new taxes," social programs, and defense come to dominate the need for university science facilities. A "won't pay" policy would preclude facilities grants, and it might also open the way for caps on indirect cost rates and elimination of universities' tax benefits . . .

When the scope of a problem is unknown, as with the need for academic research facilities, questions of which is the most appropriate policy is even harder to answer. To this end, a six-university consortium, called the Center for Policy Research and Education, has been established to study university finance and cost containment, investigating "... growth by substitution rather than by adding on cost."[5] In the meantime, neither universities nor the Federal Government face the prospect of easy solutions.

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[1] Quoted in Karen Grassmuck, "Colleges Scramble for Money to Reduce Huge Maintenance Backlog, Estimated to Exceed $70 Billion; New Federal Help Seen Unlikely," *The Chronicle of Higher Education*, vol. 37, No. 6, Oct. 10, 1990, p. A34.

[2] Other administrative questions include: a single program or a line item in the budget of each research agency, a separate amount for repair and renovation v. new construction, and an institutional matching requirement. For further discussion, see Government-University-Industry Research Roundtable, "Research Facility Financing: Near-Term Options," working draft, February 1991.

[3] Drawn from William E. Massy, "Capital Investment for the Future of Biomedical Research: A University Chief Financial Officer's View," *Academic Medicine*, vol. 64, 1989, pp. 435-437. The dollar estimates for construction he cites are drawn from National Science Foundation, *Scientific and Engineering Research Facilities at Universities and Colleges: 1988* (Washington, DC: 1989).

[4] On the cost-efficiency of academic fundraising, see Liz McMillen, "A Study to Determine the Cost of Raising a Dollar Finds That Average College Spends Just 16 Cents," *The Chronicle of Higher Education*, vol. 37, No. 1, Sept. 5, 1990, pp. A31-32.

[5] See "Education Finance," *Stanford Observer*, November-December 1990, p. 14. The Department of Education's Office of Educational Research and Improvement is funding the consortium consisting of the University of Southern California, Rutgers-The State University of New Jersey, Harvard University, Michigan State University, the University of Wisconsin at Madison, and Stanford University. The Stanford component, at the Institute for Higher Education Research, will be headed by William Massy.

SOURCE: U.S. Congress, Office of Technology Assessment, Federally Funded Research: Decisions for a Decade, OTA-SET-490 (Washington, DC: U.S. Government Printing Office, May 1991).

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Daryl E. Chubin

Biographical Sketch

Daryl Chubin is Senior Analyst in the Science, Education, and Transportation Program, Office of Technology Assessment, U.S. Congress. Before joining OTA in 1986, he taught for 14 years at Southern Illinois University (Edwardsville), Cornell University, the University of Pennsylvania, and Georgia Institute of Technology. He was Professor in the School of Social Sciences at Georgia Tech and former director of its M.S. Program in Technology and Science Policy. He is a 1968 graduate of Miami University (Ohio), earning A.M. and Ph.D. (1973) degrees at Loyola University (Chicago).

Dr. Chubin's research has centered on the social and political dimensions of science and technology: science policy (especially as related to research misconduct and peer review), public understanding of science, interdisciplinary teamwork, and education and human resources. He has published numerous articles, chapters, and commentaries, and five books, including Science Off The Pedestal: Social Perspectives on Science and Technology (coedited, Wadsworth, 1989) and Peerless Science: Peer Review and U.S. Science Policy (coauthored, SUNY Press, 1990).

Chubin was Project Director for OTA's May 1991 report, Federally Funded Research: Decisions for a Decade, and the June 1988 report, Educating Scientists and Engineers: Grade School to Grad School. He is a contributing editor to BioScience and an advisory editor to four other journals. In 1990 he was elected a Fellow of the American Association for the Advancement of Science.

Chubin is married and resides with his family in Herndon, VA. His wife, Vicki, is a special education (learning disabilities) teacher in Fairfax County Public Schools. His son, Rand, attends the University of Wisconsin-Madison, and his daughter, Jessica, is a student at Oakton High School.

June 1991

Mr. **Wolpe**. Thank you very much, Mr. Chubin.

I would now like to turn to Dr. Williams.

TESTIMONY OF DR. LUTHER S. WILLIAMS, ASSISTANT DIRECTOR, EDUCATION AND HUMAN RESOURCES, NATIONAL SCIENCE FOUNDATION; ACCOMPANIED BY DR. DAVID SANCHEZ, ASSISTANT DIRECTOR, MATHEMATICAL AND PHYSICAL SCIENCES, NATIONAL SCIENCE FOUNDATION

Dr. **Williams**. Mr. Chairman, the report of Project Kaleidoscope is a rich and remarkable document. It would justify the attention and interest of any one if it had simply contained the letter addressed to Dr. Massey, the Director of the Foundation.

This report is important in the sense that it reminds us in several places of the difficulties that still confront science and mathematics education. But in contrast to a plethora of other reports, it is other than a lament. I would observe that others have done that with sufficiency.

Rather, this report seeks to analyze, to remind and to state a purpose. It has analyzed our math and science education system at the undergraduate level, with emphasis on the interaction between the various components. It has reiterated the manifold educational objectives, with emphasis on diversity and scale of the need and the need to address all participating institutions.

The report also proposes a way, a credible and comprehensive way, a way that would build on our present knowledge base, our strengths, and gauges our determination and would marshal intellectual and financial resources in order to net improvements.

I cannot tell you that at the Foundation we will drop everything in response to this report. But I can tell you, on behalf of all my colleagues and the director, that the vision of this report, its explicit recommendations, are consistent with our current programs and our planning activities. We obviously intend to employ it on a continuing basis.

I would like now to turn to the programs of the Foundation in the context of this report. Before doing so, I would like to make a statement in response to the comments earlier in the hearing. Reference was made to the level of funding for education and human resource activities in the Foundation, starting in the 1960s, compared to basically the elimination of the programs in the 1980s and today.

Starting from the early 1980s, the Education and Human Resources effort at the National Science Foundation has grown from less than $50 million to the present level of in excess of $400 million. The increment for the last five to seven years has exceeded significantly the overall rate of increase of resources for the National Science Foundation.

Said another way, education and human resources has grown disproportionately to the funds available for research.

With respect to our present programs, they represent those activities that are organized with the Education and Human Resources Directorate that I manage, as well as programs, most of which have been referred to today, that are actually funded by the

Research Directorate, in which I have a collaborative role, but they are not my line responsibility.

Consistent with the overall policy decisions in the Foundation to have Education and Human Resources activities beyond the purview of the Education and Human Resources director, in the research Directorates, there is a process of targeting resources in those Directorates for undergraduate activity, in contrast to precollege.

In fact, for the fiscal year 1992 budget request of the Foundation, the division of that request between the Education and Human Resources Directorate and the Resources Directorate is as follows. Our share of it is—it is roughly 50-50—49 to 61. That in my view is an important point to make.

What are our programs? As you know and as has been indicated by others we have long been concerned with the overall quality of math, science and engineering, and emphasizing engineering education at the Foundation. To raise the quality of undergraduate activity, we are primarily concentrating on three programs, a trio, primarily with the Education and Human Resources Directorate.

The first program you heard about this morning was the Instrumentation and Laboratory Improvement. This program was designed to improve laboratory instructions through the use of modern instrumentation.

The program in particular places emphasis on leadership projects in laboratory developments, and it provides, as you heard, a cost-sharing of the acquisition of modern instrumentation, designed to increase the effectiveness and efficacy of laboratory experiences, to make sure that current technology is introduced through instrumentation and we actually use instruments in innovative ways in teaching laboratories.

The second program under the Education and Human Resources Directorate is the recently-initiated Course and Curriculum Development program. I term it undergraduate, but this is an effort that is almost entirely given to the two introductory years, the first two years in the undergraduate sequence. Primacy is quite frankly being given to the freshman years.

The goal here is essentially to engage quality instructors in science and mathematics and engineering courses as appropriate for all participating students. Clearly what we are attempting to do is promote the requisite change in the instructions in order to ensure that these undergraduate courses facilitate the retention of students in the process and focus on courses and curriculum as well as the laboratories in engineering, mathematics and the sciences.

While this comprehensive program is new, we have had for several years an effort in calculus focusing only on one course, and a program in engineering.

The third major program focuses on the undergraduate faculty in science and engineering. The Faculty Enhancement program is designed straightforwardly to improve the disciplinary capabilities and the teaching skills of faculty members who do undergraduate instruction, hopefully paralleling the focuses on the introductory courses.

Grants are made to single institutions or to coalitions to conduct regional or national seminars, conferences, short courses, and similar activities for groups of faculty members in which their participation would occasion increased knowledge of new techniques and new developments in the field.

Each of these programs is designed to improve instruction in special ways. Each is responsive to changes in needs. We continue to examine the programs, undergraduate institutions of all types may participate in them, and we stress the programs, instrumentation, undergraduate course in curriculum development, faculty enhancement, for them to operate in concert to engender direct synergy.

I should observe that at NSF we are concerned with all students in science and engineering education, the opportunity for all students to have substantive courses in science and mathematics.

One justification for the same is the nature of modern society and culture requires that citizens or students be expected to bring to bear serviceable knowledge of science and mathematics in their lives, so issues of numeric and science literacy are vital, quite independent of whether individuals are on the science and engineering track.

We are also equally concerned with the congruence between our undergraduate agenda and our precollege agenda, where we have a fundamental responsibility for training the next cadre of first-class math and science teachers. These introductory courses are critical to that proposition.

So the precollege agenda is linked, if you will, to the undergraduate activity. In fact, in terms of planning, the Foundation has recently developed a new program that will focus on math and science teaching centers, in which we are asking for deliberate collaboration between science and math faculty and faculties of schools of education, to ensure the requisite preparation and enhancement of the next generation of math and science teachers.

For all these programs, effective last fiscal year, we have put in place an evaluation component to ask the very hard questions that were raised earlier with respect to the efficacy of our programs and how in fact they need to be revised.

Equally so, recognizing that we have limited resources and we are attempting to impact a diverse set of institutions—research institutions, comprehensive institutions, liberal arts institutions—we are giving increased attention to dissemination of exemplary models that result, not necessarily being directed to the use of them, but certainly making clear to the broad community those projects that NSF has supported.

The report of Project Kaleidoscope shows us the potential for the Nation's liberal arts colleges to extend and strengthen science and math education. Similar reports have dealt with universities at other sectors, and as I said earlier, the Foundation certainly will give attention to that report.

But that report is framed in the context of a variety of other reports we have supported. We have a series of reports that have looked at the issue of undergraduate education, and each of its broad disciplines in the sciences, biology, chemistry and physics.

We recently conducted a workshop in two-year colleges. We looked specifically at programs for minorities and all of which has now been reflected in the strategic plan.

I would like to close by making several comments in response to the letter that I sent to you, requesting information on the coordination of the undergraduate programs in the Foundation.

In June 1980, there was a reorganization of the Education and Human Resources activities in the Foundation, a transition from the Science and Engineering Directorate to the Education and Human Resources, to move the Human Resources programs, which were disparately located around the Foundation, primarily focusing on minorities, women and persons with disability, into one division, which is now an organized division under my direction.

Coincident with that was the effort to address another issue, and that was to create a mechanism by which I, as the Assistant Director of Education and Human Resources, would on a continuing basis interact with my colleagues who manage the programs in the Research Directorates. There was created what is called the Education and Human Resources Policy Committee.

The principal reason for the creation of it was to share information to coordinate, to try and address common problems, and make sure there was collaboration. That program, the composition of the committee, is therefore all the program assistant directors of the Foundation. It has only been in operation for about a year, and in my view, experience shows that it works. It operates informally and by consensus.

Recently, one of the efforts addressed by the committee was the disposition of the coordinating function for four programs that are funded by the research directors, not the Education and Human Resources Directorate account. The question at issue was not the transfer of fiscal management responsibility, but coordination. I want to speak specifically to decisions that we made.

Research Experience for Undergraduates, that operates in all the research Directorates. We felt it was important that one of the Directorates assume the responsibility for overall coordination of it, certainly from the point of view of each fiscal year report, to get a sense of how well we had progressed, where each Directorate had progressed to in reaching their targets.

In fact, my colleague with me, Dr. David Sanchez, who is the Assistant Director for Mathematical and Physical Sciences, has that responsibility.

The second program, that was previously in another component of the Directorate, a program focusing on providing research grants, essentially planning grants, for minority faculty members, it's called Minority Research Initiation, it was proposed initially that that program be coordinated by the Engineering Directorate. We decided not to make that change. It now remains the coordinating responsibility of my Directorate.

The third program, the program that focuses on research grants for women, the career and advancement awards, that program is coordinated by the Assistant Director of the Directorate of Biological and Behavioral Sciences.

Lastly, to Research in Undergraduate Institutions. We have decided it was not necessary that they have coordination of that program. Certainly in light of the issues that have been raised prior to this hearing and during the hearing, most assuredly we will reexamine that issue.

Thank you.

[The prepared statement of Dr. Williams follows:]

STATEMENT

of Dr. Luther S. Williams,
Assistant Director for Education and Human Resources,
National Science Foundation,

at the July 11, 1991 Hearing of the
Subcommittee on Investigations and Oversight,
Committee on Science, Space, and Technology,
United State House of Representatives

Mr. Chairman and Members of the Committee:

It is a pleasure to be here today to discuss the report of Project Kaleidoscope: "What Works: Building Natural Science Communities; A Plan for Strengthening Undergraduate Science and Mathematics." Project Kaleidoscope was one of a small number of efforts funded by the National Science Foundation to develop plans for strengthening undergraduate education in the several sectors of higher education -- in two-year and four-year colleges, in comprehensive universities, and in research universities.

The report of Project Kaleidoscope is a rich and remarkable document. It reminds us in several places of the difficulties confronting science and mathematics education in the United States today -- but it is not a ceaseless lament. Its approach is not to alarm (others have done that to sufficiency) but to analyze, remind, and propose.

- The report analyzes our system for education, the interactions among the parts of the system, the social and political context in which the parts function, and both the problems and the opportunity.

- The report reminds us of our manifold educational objectives, of the diversity and scale of our needs to teach and to learn, of the complexity of the task of improvement, and of our resources and our resolution.

- The report proposes a way -- a credible and comprehensive way -- a way that builds on our strengths, engages our determination, marshals our physical and intellectual resources, and which promises to work.

I can tell you that the vision of this report is consistent with ours and that we will learn and perhaps teach from it.

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This Statement is a preliminary response to the four Initiatives proposed in the report of Project Kaleidoscope and its several recommendations to NSF. An excellent introduction for it appears on page 5 of the report:

> "Liberal arts colleges have no monopoly on programs that work in undergraduate science education. Institutions of all kinds have achieved success in baccalaureate science education; not all independent colleges have succeeded at science and mathematics education; and even the best colleges have failed with certain students. Anyone who has been involved seriously in education knows that one must deal constantly with imperfection while keeping one's eye on the ideal."

In that spirit, we present here an overview of what the Foundation is doing now and is planning to do with its programs at the undergraduate level.

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The report assigns highest priority to four initiatives:

I. Reforming the introductory courses in undergraduate science and mathematics;

II. Supporting the integrated teacher/scholar role of undergraduate science and mathematics faculty;

III. Making disciplinary content and active learning central to the education of K-12 teachers of science and mathematics; and

IV. Developing partnerships focused on strengthening undergraduate science and mathematics.

The National Science Foundation is firmly committed to all four of these initiatives; its current and planned aggregates of specific programs are designed to achieve their objectives.

NSF believes that it should foster a national community of scholars by engaging large numbers of instructors of undergraduates in improvement activities that will result in greater attention by faculty to undergraduate instruction and that will reward outstanding teachers.

NSF considers the task before the Nation to be revitalizing the instruction of undergraduates rather than reorienting the academic culture from research to teaching. To strengthen instruction, some faculty should do more rather than less scholarship, some should pursue different scholarship, and some need to engage teaching in new ways.

To achieve a new balance, grant programs must help rechannel faculty activity. NSF's planning recognizes the needs of faculty at research universities, comprehensive universities, four-year colleges of various descriptions, and two-year colleges. NSF's programs are designed to make instructional innovation and improvement a viable arena for professional activity.

The long-term solution requires more than making a few large, widely publicized awards to already exemplary teacher/scholars. We must find ways to engage the minds and energies of thousands of faculty in all kinds of institutions in a huge network of contacts, bright ideas, and activities. This argues for programs that make grants to many individuals for a large variety of activities.

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Initiative I. Reforming the introductory courses in undergraduate science and mathematics.

- *Instrumentation and Laboratory Improvement; Introductory Courses.*

The **Instrumentation and Laboratory Improvement** Program (ILI) aims to improve the quality of all undergraduate laboratory instruction in science, engineering, and mathematics, and for both majors and nonmajors. To achieve this goal it makes grants for projects to enhance the quality of laboratory work through development of experiments and courses which use contemporary equipment and techniques.

Projects in two broad categories are supported: (1) *Instrumentation*: Model and standard setting projects to improve the quality of laboratory instruction through creative use of modern instrumentation and advanced technologies; and (2) *Laboratory Improvement*: The conception, design, and testing of new approaches that are cost effective, powerfully stimulative of learning, and that reflect actual science and engineering practice.
During the next few years:

- A substantial ILI effort will continue to treat as a special target the improvement of large-enrollment introductory laboratories.

- A major new effort will be initiated to bring about significant and widespread change in laboratory instruction. This ILI thrust will support laboratory improvement projects of two kinds: one will provide incentives for individual investigators to develop laboratories and modules by supporting personnel, travel, support services, and dissemination costs as well as those for instrumentation; the other will provide funding to groups of institutions and organizations for comprehensive projects to revise whole laboratory sequences. And,

- A new ILI thrust will make small awards for the dissemination of exemplary laboratory improvement work, whether funded initially by NSF or not.

- *Course and Curriculum Development Program; Local Improvements and Comprehensive Projects for Introductory Courses.*

There is need for a variety of projects, large and small, to stimulate faculty efforts that will yield new undergraduate courses and curricula. In this area, the Foundation will emphasize: re-thinking professional and pre-professional curricula; courses for nonscientists; timely applications of new knowledge and technologies; involvement of research-oriented faculty; and two critical articulations -- high school with college, and two-year institutions with four-year.

NSF has three undergraduate course and curriculum programs. One focuses on instruction in the calculus, and another on the engineering curriculum (it was merged recently into the Engineering Education Coalitions Program); these have been running since 1988. The third one is new: **Undergraduate Course and Curriculum Development** Program (UCC) in engineering, mathematics, and the sciences.

The UCC Program provides support for the design, development and testing of major changes intended to increase the effectiveness and efficiency of undergraduate courses, curricula, and attendant laboratories in engineering, mathematics, and the sciences. Emphases are placed on timely applications of new knowledge and technologies; re-thinking professional and preprofessional curricula; courses for nonscientists; articulation with high school science and mathematics; and involvement of research-orienteo faculty.

NSF is planning that UCC will:

- Establish a strong focus on the critically important but neglected introductory-level courses in engineering, mathematics, and the sciences. In a major effort, projects will be supported to make these courses attractive and effective not just for potential majors in their subjects, but for the much more numerous "other students" -- including technical nonmajors, non-science majors, and future K-12 teachers;

- Initiate major curriculum improvement efforts in the physical, biological, and behavioral sciences like the Undergraduate Engineering Curriculum and the Calculus Curriculum Development initiatives;

- Foster broader participation in calculus course and curriculum development and assessment by adding adaptation, refinement, and implementation projects to the course and curriculum improvement activities supported at present;

- Develop incentives that will increase the involvement in curriculum reform activities of science, mathematics, and engineering faculty members in all kinds of institutions -- to precipitate a change in the academic culture such that undergraduate teaching and curriculum development become respected and rewarded once more; and

- Establish a number of select centers for undergraduate science, mathematics and engineering instruction, each of sufficient size to provide a viable nucleus of talent to work on educational problems at that level. (Inquiries from the higher education community indicate interest in foci such as the individual scientific disciplines, various multidisciplinary combinations, and several emerging interdisciplinary areas.)

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Initiative II. Supporting the integrated teacher/scholar role of undergraduate science and mathematics faculty.

- *Research Experiences for Undergraduates.*

The Research Experiences for Undergraduates Program (REU) is managed by the individual research directorates. It promotes direct collaborative participation in academic or industrial research by promising undergraduate students. The Program (1) supports the creation and operation of undergraduate research sites in established industrial and academic research laboratories, and (2) provides access to research experiences by incrementing current NSF research awards so that undergraduate students can be brought onto the research team.

NSF's planning in the undergraduate research area includes:

- Continued expansion and evolution of the REU program with emphases on involvement of students from underrepresented groups, and of those enrolled in colleges that do not have substantial established research programs.

- Establishment of a complementary program to support student research projects under the direction of a faculty member (complementing REU, which supports students to work on faculty research projects).

- Special programs to expose undergraduates to the geosciences, and computer and information sciences (planning will be started on new approaches to introductory biological and behavioral science courses).

- *NSF Programs for Undergraduate Faculty.*

This is an area of critical concern. There is demonstrated need for activities which will enable faculty to remain intellectually vigorous, current in their disciplines, aware of up-to-date curricular developments, and prepared to stimulate student learning. This need exists for faculty at all kinds of collegiate institutions -- research universities, primarily undergraduate colleges, and two-year colleges.

Faculty cannot gain currency in their disciplines through "one-shot" activities; continuing participation in a community of scholars/teachers is required. Similarly, widespread improvement of instruction and curriculum will not be achieved through the successful marketing and adoption of the work of a few reformers; support must be provided to faculty members all across the nation for individual and local improvement efforts.

The Foundation supports several programs designed to assist the professional growth of undergraduate faculty members. One of these is the **Undergraduate Faculty Enhancement** Program (UFE); it supports efforts to improve the disciplinary capabilities and teaching skills of faculty members who are involved primarily in undergraduate teaching. Grants are made to single institutions or to coalitions to conduct regional or national seminars, conferences, short courses, workshops, or similar activities for groups of faculty members in which the participants learn about new techniques and new developments in their fields.

During the next few years:

- A major new thrust will focus on improving the quality of teaching and learning in the Nation's two-year colleges through partnerships between the two year colleges of a region and at least one four year college or university. NSF will fund the initial interaction and lend continuing support to projects of up to five years duration that address faculty development through curriculum improvement activities, joint research projects, laboratory innovation, and team teaching.

- Another new thrust will support workshops that bring together faculty from different types of institutions to work together on the development of an important educational product in a disciplinary or interdisciplinary area.

Extending the Undergraduate Faculty Enhancement Program, the Foundation will support a program for individual faculty members who have demonstrated potential for major leadership roles in undergraduate education. The program will enable them to: investigate undergraduate teaching and student learning; undertake curriculum development projects; and, become part of a national network of teachers/scholars, actively involved in the development and dissemination of innovations in undergraduate and precollege science and mathematics education.

Research is one of several critical foci in the professional activities and development of undergraduate faculty members. Part of NSF's mandate to ensure the vitality of the Nation's scientific and technological enterprise includes concern for the quality, distribution, and effectiveness of such research in science, mathematics, and engineering. The **Research in Undergraduate Institutions** program (RUI) is designed to: (1) support high quality research by faculty with active involvement of undergraduate students; (2) strengthen the research environment in academic departments that are oriented primarily toward undergraduate instruction; and (3) promote the integration of research and education at predominantly undergraduate institutions.

Through RUI, NSF provides support for research and research insturmentaton in non-doctoral departments in predominantly undergraduate institutions. Proposals to RUI must address the expected impact of the proposed research on the research and training environments of the department. Each of NSF's research directorates has a RUI target; this assures that RUI is fully integrated into the regular research programs of the Foundation. RUI's FY1991 target is $14.5 million; the target proposed for FY1992 is $18.7 million.

- There has been increased support for RUI each successive year since its inception in FY1984, and all targets have been exceeded. NSF plans to continue RUI's steady growth.

NSF has two programs designed to assist the professional growth of undergraduate faculty members who are women. One of these is the **Visiting Professorships for Women** (VPW) Program. The entry and advancement of women into faculty positions in science and engineering on a par with men, particularly in the physical sciences and engineering, continues to be a problem. The VPW Program enables experienced women scientists and engineers to undertake advanced research at a host institution -- a university or college which has the necessary facilities and resources. In addition to her research responsibilities, the visiting professor undertakes lecturing, counseling, and other "interactive" activities to increase the visibility of women scientists in the academic environment of the host institution and to provide encouragement for other women to pursue careers in science and engineering.

- The Foundation plans to expand the VPW Program in the future; other changes in the Program will increase its flexibility and usefulness.

The other NSF program addressing the professional growth needs of women undergraduate faculty members is the **Faculty Awards for Women Scientists and Engineers** Program (FAW). It is a new effort designed to recognize some of the nation's most outstanding and promising women scientists and engineers in academic careers of research and teaching; to help retain them in academia by providing research support for a five-year period; and to facilitate further development of their careers. Nominations are made by their institutions on behalf of tenured faculty women who are not yet full professors.

- The FAW Program is being initiated with approximately 50 awards in FY1991 and 50 more in FY1992. As the program matures, eligibility may be broadened to include women faculty members who have not yet achieved tenure; and awards will be distributed differentially among disciplines in an effort to address the most severe underrepresentations (e.g., in Astronomy, Ocean and Atmospheric Sciences, Physics, Computer Science, and Engineering).

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Initiative III. Making disciplinary content and active learning central to the education of K-12 teachers of science and mathematics.

- *Teacher Preparation Activities.*

The Foundation's **Teacher Preparation** Program supports the development and evaluation of innovative approaches to the preservice education of future teachers of mathematics and science. Special interests of the program are recruitment to teaching of members of underrepresented groups -- women, minorities, and the disabled; preparation to teach more than one subject; and projects that address expert-identified shortfalls in the content of teacher education and the intense problems in the profession that are arising because of current demographic trends. The Program does encourage colleges and schools of education "to redirect the structure and content of their teacher preparation programs to focus more directly on science and mathematics," and many of the projects supported do emphasize "an active, investigative, hands-on, content-based approach."

The Foundation is considering a number of major additions to its present program of support for teacher preparation activities.

The projects supported by the Teacher Preparation Program are designed to yield new teachers who are very deep in their subject matter knowledge and very skilled at teaching. The accumulated experience of the Program has given us the building blocks for a much different way of addressing the Teacher Preparation task -- a different way that does not just tinker with the present system, but which involves a basic rethinking, redesigning, and restructuring of the whole teacher preparation process -- and the creation, as a result, of a number of **Teacher Preparation Centers** (TPC).

One category of changes in the system would be intended to *change the culture* and might include:

- restructuring the relationships between the universities and the schools through establishment of linkages and building of human resources, and remaking the ways in which members of the universities' education and disciplinary faculties relate to the teacher preparation activity and to each other;

- connecting teacher preparation to the huge task of teacher enhancement, and building leadership for future teacher enhancement activities;

- rethinking and rebuilding the responsibility, accountability, and policy-making structures within the universities and between the universities and the state departments of education that control licensure; and

- establishing mechanisms for professional development of teachers at every stage of their careers -- novice, journeyman, master, and senior.

A second category of changes in the teacher preparation system would be intended to *expand the knowledge base* -- and, of course, to apply and build on the expanded base; it might include:

- doing research on learning and teaching; on the content, development, and presentation of instructional materials; and on educational methodologies and technologies;
- maintaining a robust graduate program, and sharing and disseminating research through exchanges between universities of faculty members and graduate students; and
- integrating knowledge of discipline, of students, and of pedagogy.

As presently constituted, universities provide knowledge of discipline, of students, and of pedagogy quite independently of each other. But, the classroom teacher functions at the intersection of those domains. Teacher Preparation Centers could provide far more effective preparation for that service than present mechanisms. NSF's support would be for faculty time, possibly for undergraduate and graduate student scholarships, and for support activities.

- *Teacher Enhancement Activities*.

Among the important objectives of the Foundation's education programming are improvement of teacher capabilities; positive reform of the curriculum; harmonious interaction of teachers with administrators; better articulation between system levels - elementary, middle, and high school; and improved student achievement.

The Foundation's **Teacher Enhancement** Program is encouraging proposals that are moving out in several new directions:

- to develop materials for teachers that will help them teach better; these would not be textbooks for students or materials for direct classroom use (e.g., resource volumes on biotechnology for biology teachers, materials science for chemistry teachers, chaos and fractals for mathematics teachers -- cutting edge topics probably not covered in their undergraduate preparation);
- to develop materials on how to conduct effective inservice activities for teacher enhancement (how do adults learn; how does one teach his peers?); and, combining the two,
- proposals for "leadership" projects in which the participants are teachers with the potential to be leaders in their respective communities -- teachers who will, as a result of their project experience, be qualified to teach other teachers through workshops and other inservice activities.

The Teacher Enhancement Program is beginning to fund projects that cover much or all of a major city (an informal "urban initiative"). One such is a City of Baltimore (MD) system-wide effort to improve science education; there are similar projects in Tampa (FL), Cleveland and Cincinnati (OH), and Pasadena (CA). There is also an elementary schools mathematics project of this type in Boston (MA).

The first awards under the NSF **Statewide Systemic Initiatives** Program (SSI) [to Connecticut, Delaware, Florida, Louisiana, Montana, Nebraska, North Carolina, Ohio, Rhode Island, and South Dakota] are for projects that involve undergraduate institutions in many ways with efforts to improve science and mathematics education in the schools of whole states.

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Initiative IV. Developing partnerships focused on strengthening undergraduate science and mathematics.

- *Colloquia to Discuss "What Works" in Undergraduate Science and Mathematics Education.*

Such colloquia would be part of what the Foundation calls its undergraduate **leadership activities**. NSF's leadership activities are intended to be bold steps to establish and maintain the leadership of the Foundation in efforts to advance and maintain the quality of undergraduate education in engineering, mathematics, and the sciences; and to stimulate interest in- and active support of- undergraduate education by other sectors, i.e., scientists, academic institutions, the States, the private sector, and other Federal agencies.

The Foundation plans aggressively to stimulate discussion throughout the academic community of issues important to the character, quality, and effectiveness of undergraduate education -- e.g. undergraduate science education in institutions of different types; the curriculum and articulation; and dissemination of innovations from the source institution to other campuses.

Among other leadership activities to be pursued by NSF during the next few years are these:

- Preparing short- and long-range program plans for NSF support of undergraduate science, mathematics, and engineering education -- in consultation with the other NSF Directorates, professional groups, the academic communities, and persons from the private sector;

- Developing programs to attract senior research faculty to activities that will improve lower division undergraduate instruction;

- Encouraging cooperation and sharing of resources among colleges and universities to increase effectiveness and help control the costs of undergraduate instruction; and

- Supporting networks among the States and local higher education decision makers to disseminate information, share ideas, and develop cooperative strategies to improve the health of higher education in the sciences.

NSF has found an important mechanism for both leadership and planning in the program of workshops and conferences on undergraduate education conducted by EHR's Division of Undergraduate Science, Engineering, and Mathematics Education (USEME) in conjunction with NSF's research directorates. The participants in these activities are distinguished academic and industrial scientists, engineers, and administrators.

The current set of USEME workshops and conferences is focusing on problems and opportunities of science and mathematics education in institutions of various types. Reports are now available that examine two-year and community colleges, and comprehensive state universities; the report of Project Kaleidoscope speaks to the problems and opportunities in the liberal arts colleges; and in late 1991 a similar report should be completed on research universities.

These workshops, and the reports of their findings and recommendations, are contributing significantly to the growing national understanding of- and concern for- the needs of undergraduate education. The regional and national colloquia proposed in the Kaleidoscope report would seem to be a logical extension of the workshops activity.

- *Partnerships.*

The Foundation mounts several endeavors to create a variety of partnerships to address the diverse predicaments of science and mathematics education. Virtually all of them do or can involve liberal arts colleges. For example:

- **Alliances for Minority Participation** (AMP) is a new program designed to effect fundamental changes in the education of underrepresented minority students in science, mathematics, and engineering. The goals of the program are to raise the quality of education received by such students and to increase the number of them who earn engineering and science baccalaureate degrees, go on to undertake graduate study, and attain the Ph.D.

  The "alliances" in AMP's name are coalitions among academic, governmental, industrial, and non-profit organizations established to create comprehensive approaches to the achievement of the Program's goals. The academic allies are usually a cluster of universities and two-year and four-year colleges.

  The AMP program focuses on the undergraduate level, but individual projects include activities that affect minority student advancement through one or more of the critical decision points on the educational pathways to science and engineering careers: i.e., the transitions between high school and college, 2- and 4-year colleges, undergraduate and graduate study, and academia and the workplace.

- The **Private Sector Partnerships** Program (PSP) was established in FY1991 to foster use of the intellectual capital of business and industry in addressing the manifold needs of K-12 education in partnership with large urban schools, school districts, and regional consortia. [PSP came into being in 1988 through the first of a series of special solicitations within another EHR program.] PSP projects exemplify a variety of new kinds of collaborations to improve science and mathematics education.

  PSP will continue to marshall the commitment and intellectual capital of business and industry to work in partnership with large urban schools, school districts, and regional consortia to improve education in science and mathematics; and emphasize projects in which the participation of scientists from business and industry is the enabling element.

- As interactions within an institution of a number of high quality programs are synergistic, so are consortial interactions among institutions. Hence, during the next five years the USEME Division plans to:

  Initiate a program of challenge grants to colleges, universities, and consortia to support correlated and integrated sets of projects designed to improve undergraduate instructional programs (with emphases on cost-sharing, and on encouragement of partnerships with private sector organizations -- including the science and engineering professional societies).

  Provide, through a major subprogram, incentives for forming consortia each involving a lead university (or 4-year college) and a group of 2-year colleges. These consortia will work on articulation between these types of institutions and to develop coordinated projects for improving lower division instruction in mathematics, the sciences, and pre-engineering technology.

- *Computer and Telecommunications Networking.*

Staff in NSF's Directorate for Education and Human Resources (EHR) and Directorate for Computer and Information Science and Engineering (CISE), in consultation with expert advisors drawn from education agencies, schools, and higher education, have analyzed the state of the art in computer-communications networks, the level of networking activity and know-how among educators and teachers, priority needs in science and mathematics education, and opportunities afforded by the technology.

Based on this analysis, NSF has begun to establish new, more powerful linkages and collaborations among persons and technological resources involved in scientific research and education in science, mathematics, and engineering. These linkages and collaborations are supported by digital communication networks and computer-based resources through NSFNET and the National Research and Education Network (NREN) as proposed in the FY1992 Initiative on High Performance Computing and Communications of the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET).

The new organizational arrangements and technology resources supported by these NSF programs will add value to and make more efficient and effective the processes by which new knowledge, tools and materials are created, communicated, understood, and implemented by teachers and students at all levels of education. This infrastructure-building program is intended as the first phase of a strategy leading to more widespread implementation of advanced technologies and curricula in education.

NSFNET, the connected *Internet*, and the NREN will help make science education -- especially NSF-supported education projects -- more responsive to changing national and local needs. Computer communications networks will support new paradigms of learning and teaching -- paradigms more responsive to current and future national needs for education in the information age.

* * *

The report of Project Kaleidoscope shows us the potential of the nation's liberal arts colleges to extend strengthen science and mathematics education. Just about a year ago, a report entitled "Formula for Reform" showed us the important contribution that the comprehensive universities could make to such efforts. The Foundation is determined that the resources of ALL of higher education be brought to similar service. The United States' systems of higher education are the most comprehensive in the world; their strength is great, but must be increased; that strength must applied to the improvement of education in the nation's schools.

Mr. Wolpe. Thank you very much, Dr. Williams. I have a series of questions that relates to that last point. But I believe Mr. Nagle seemed eager to ask a question a moment ago.

Mr. Nagle. Just the one. I have three questions, but the one you have already answered. I wanted to break in just to confirm it.

OTA would like to ask if the Project Kaleidoscope model is an NSF educational priority, and I gather it is not, by what you said. It is simply one of several studies you are going to be looking at.

Dr. Williams. Well, it's a priority. It is not the priority. It is a very important one, and it is important in the following regard: it deals with the very important three major sectors that we have responsibility for, comprehensive universities, research institutions, and liberal arts institutions. While it does not specifically speak to minority institutions, I think some attention has been given to that collection of institutions.

So certainly in terms of the institutions it represents, it will be integral to our planning process. But it is not the priority.

Mr. Nagle. Thank you.

Mr. Wolpe. Thank you, Dave. Before turning to the last issue, Dr. Williams, I want to ask Dr. Chubin a question. The OTA analysis—I think it parallels very much the general thrust of the recommendations of the Project Kaleidoscope report, the emphasis on the role of the small liberal arts colleges, the integration of research and education.

My question is, are there any significant points of differences or nuances or emphasis in the OTA evaluation that we ought to at least be focused upon in comparison to the Project Kaleidoscope undertaking?

Dr. Chubin. Let me just comment on the partnership component of Project Kaleidoscope. If I have a criticism, it doesn't distinguish this particular project from a project that might be done by two-year and community and junior colleges, or a different project that would be done by research universities.

I think there is a reliance on Federal support, and in this particular case, NSF support, to ensure the continued success of some of these activities that I think first, are unnecessary, and second, may be wishful thinking.

In other words, if one believes that partnerships work, and given the participation of the foundations that are already involved in this project, then the participating institutions need to devise ways of making their dollars go further without expecting NSF to bail them out.

In my written statement, there is a line that says something to the effect that NSF is asked to be all things to all people. It is being stretched to the limit. If anything, Project Kaleidoscope has already demonstrated the capability to make things work on these various campuses that are participating. Given the mobilization of resources and of faculty and given the leadership of the presidents involved, I am very optimistic about that.

But I would hope that would not tie the future success and the spinoffs of that success to increased NSF funding. I perhaps share with you, and perhaps not, a concern that that funding won't be forthcoming. I don't want them to think that they are so utterly dependent on it that if it's not forthcoming that their efforts become interrupted or perhaps are terminated.

Mr. **Wolpe**. Thank you. I did want to pursue this question of research, the RUI program. We have received testimony prior to today that emphasized the critical role that the RUI program plays at predominantly undergraduate institutions. So when we began to rather innocently ask some questions, we were a little surprised by the reaction and response within NSF to those questions.

Does the NSF consider the RUI program to be a successful program, or are there problems you have with it?

Dr. **Williams**. I think it is a successful program, and I would argue that it is a very important one. And I am absolutely confident from the character and nature of discussions I have had with my research colleagues, the assistant directors and research directors, I am speaking for everyone. There is no question that it is highly valuable.

Mr. **Wolpe**. Is there a central office right now that is overseeing this program at the moment?

Dr. **Williams**. No.

Mr. **Wolpe**. There was a central office previously?

Dr. **Williams**. There was an office before the reorganization. There was a division within another Directorate, the STIA Directorate, Scientific Technical and International——

Mr. **Wolpe**. It's refreshing to find someone within the agency who is not aware of the acronyms. I thought it was only us types that had that difficulty.

Dr. **Williams**. That's right. [Laughter.]

I think it's refreshing.

That was a division called Research Initiation and Improvement, and to be honest, it was at least in my view a sort of collection for a variety of programs that did not have much in common. One of the things it did was coordinate on behalf of the research directors a variety of functions.

Mr. **Wolpe**. But there was one individual that had that coordinating responsibility?

Dr. **Williams**. Yes, that's right.

Mr. **Wolpe**. Was that person located in the division of Human Resources Development?

Dr. **Williams**. That person was originally located in the Research and Initiation Division of STIA. Now, when the Directorate—when the Education and Human Resources Directorate was reorganized, was created, those personnel came to a new division called Human Resource Development. Obviously, up to the time the policy committee made the decision to transfer it, that person had that responsibility.

Mr. **Wolpe**. So at that point, the division of Human Resources——

Dr. **Williams**. That's right. Who coincidentally always had it. It was the same individual.

Mr. **Wolpe**. That was Dr. Joe Danek's office?

Dr. **Williams**. Yes.

Mr. **Wolpe**. Why was the judgment made that that office no longer coordinate and oversee RUI programs?

Dr. **Williams**. Because we honestly didn't think it was necessary. We didn't think the coordination was necessary.

I don't know if this is appropriate, because he is not sworn in, but my colleague, Dr. Sanchez, who has a very large component of this program from a research Directorate, if possible I would like for him to speak to it. I can give you my view of why I don't think it was necessary.

Mr. **Wolpe**. Would you?

Dr. **Williams**. Well, all four of these programs I just described, what distinguishes them from everything else we do is that they are not in the Education and Human Resources budget that is appropriated by the Congress. It is not my management responsibility, fiscal or otherwise.

How those programs work is that research directors get their research account. They then, in collaboration with our Office of Budget and Control, negotiate a target that says for this fiscal year, I will commit X amount for these activities, one of which is RUI.

The program people, the proposals come in——

Mr. **Wolpe**. Negotiate with who?

Dr. **Williams**. Basically with the director of the Foundation, who has to approve it. They set a target in terms of monies they are going to spend, five of them. So in effect there are five programs, if you want to view it that way. Their people set the targets, they review the proposals, they make the merit review, they make the funding decision.

It is important for the Foundation—I would argue—at the end of a fiscal year to have a report that shows what in fact has been accomplished. The policy committee that I chair has that as a continuing responsibility. That report will have bearing on how the targets are set for the next year.

The question is, should we have in effect a mailbox, and that's in my judgment, basically what the coordinating role was. A person who was conducting it had no management responsibility, had no control over finances, but was very important in having a contact with which the community could interact.

From the comments I have heard regarding it, I am certainly not adverse to reconsidering it. But if it were reconsidered, the goal would quite frankly have to be somewhat more substantial than it being a mailbox. The person really is in effect coordinating.

Mr. **Wolpe**. It was not just in the testimony today. The letter from Project Kaleidoscope to Dr. Massey, states: "Given its distributed nature, strong oversight of RUI by a single office must be reinstituted." So this is not——

Dr. **Williams**. But I don't think there was strong oversight in the first instance. The way I do bottom lines is that the person didn't have control over the budget, the person did not have control over the review of the proposals, did not have control over the award process, so at best what the person could do was provide general advice before the proposal was submitted and collect the information from the research directors and prepare a report. That was not really oversight. Coordination, maybe, but not oversight.

Mr. **Wolpe**. But you would not be adverse to having more power to oversee the program?

Dr. **Williams**. No, that's not what I said.

Mr. **Wolpe**. I was asking you a question.

Dr. **Williams**. I don't seek it. Let me tell you what I would like. I would like the RUI program internally in the program office in each of the Directorates, myself, the assistant directors, the directors of the Foundation, but most importantly the community that is served, all of us in unison, to feel that it is a highly valued program and it is working. What I am interested in are what are the deficiencies now in addressing them.

It seems to me it is important to have, if this is the case, to have some identified individual from the vantage point of the community, who could be helpful. But what I cannot do by definition is change those fundamental responsibilities that reside in the research Directorates. That is going to remain.

Mr. **Wolpe**. I understand that. But if I understand the thrust of earlier testimony, there are two or three different issues involved. One is that first of all, the targets have been reduced, at least the allocation of funds have not been sustained, commensurate with the need.

Dr. **Williams**. Absolutely. But that's true of everything.

Mr. **Wolpe**. I understand that. But to the extent—going back to the point you made that you don't have a separate budget item that could be pulled out and given a separate budget itemization, particularly in this climate, it may be more important to make that happen.

The second issue is the manner in which funds get allocated. We heard some testimony indicating that the criteria for the allocation in some instances seems to be off target in terms of the central mission and purpose of the RUI program.

Dr. **Williams**. Right.

Mr. **Wolpe**. I take it that was the reason for the desire that there be a central focus, a coordination.

Dr. **Williams**. Right.

Mr. **Wolpe**. The third issue is the notion of mission, that is without someone that really sees that as his or her principal management function, you don't have a heck of a lot of effective focused advocacy.

Dr. **Williams**. Okay. On the last point——

Mr. **Wolpe**. I have no objection if——

Dr. **Williams**. Let me respond, then I will have David respond. On the last issue, that's the one that quite frankly I am most—well, I am open to all considerations. But that's the one that seems to me could result in enhancement, if there was someone whose primary responsibility was to make sure they really understood the program and worked effectively with the community.

On the other two issues, the targets have been reached, they have been exceeded. They have been exceeded even in the years when the research Directorates took reductions in budget. So that in my judgment is not an issue. In fact, this year I can tell you where the results are.

The example that was cited about presumably the several reviews where there were inappropriate statements, sadly, in the peer review process that happens. That imperfection is no greater in my judgment in this program than elsewhere. Having one coordinator who is still not a program officer in the research directorate where the review is actually taking place is not going to materially contribute to that process.

The last issue you cited is the one which we could actually think of ways to try and address.

Mr. **Wolpe**. The decision to remove Education and Human Resources as the central coordinator was made by the EHR policy committee, is that correct?

Dr. **Williams**. Right. That's correct.

Mr. **Wolpe**. At a meeting in December, as far as I can tell?

Dr. **Williams**. Right.

Mr. **Wolpe**. Thank you.

I would like to ask unanimous consent to enter into the record the response that we received from NSF to a subcommittee document request that details that decision. I think you are familiar with the memos.

[The information follows:]

NATIONAL SCIENCE FOUNDATION
1800 G STREET, N.W.
WASHINGTON, D.C. 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR EDUCATION AND
HUMAN RESOURCES

July 9, 1991

The Honorable Howard Wolpe
Chairman
Subcommittee on Investigations and Oversight
Committee on Science, Space, and Technology
2320 Rayburn House Office Building
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Wolpe:

Enclosed are documents you requested relating to recent changes in the coordination of several programs in the Education and Human Resources Directorate at the National Science Foundation.

The EHR Policy Committee is a working group comprised of the research Assistant Directors, chaired by myself. We are not a standing committee of the Foundation, but meet informally to discuss management and policy issues related to all of the Foundation's education and human resources activities. As such, our group does not prepare or keep minutes.

I am forwarding this material, but I would request that since some of it could be exempt from disclosure to the public in order to safeguard the deliberative process of the Foundation, it not be disseminated beyond the Committee and its staff.

I appreciate the opportunity to be of assistance to you and the Committee and I look forward to the hearing on Sources of Future Research Scientists on Thursday.

Sincerely,

Luther S. Williams
Luther S. Williams
Assistant Director

Enclosure

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NATIONAL SCIENCE FOUNDATION
1800 G STREET, N.W.
WASHINGTON, D.C. 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR EDUCATION AND
HUMAN RESOURCES

December 26, 1990

MEMORANDUM

TO: Raymond Bowen
Charles Brownstein
Mary Clutter
Robert Corell
David Sanchez
Karl Willenbrock

FROM: Luther S. Williams

SUBJECT: Cross-Directorate Programs

At our December 18th meeting, we (the EHR Policy Committee) decided that the following cross-directorate programs, for which the research directorates have management and fiscal responsibilities, would be transferred in full to the research directorates. Thus, this memorandum is to reiterate that decision and to recommend to the Acting Director approval of the transfer of program coordination responsibility from the EHR Directorate to the research directorates for:

(a) Research Experiences for Undergraduates (REU) - (already accomplished);

(b) Research in Undergraduate Institutions (RUI);

(c) Minority Research Initiation (MRI) (Planning and regular) grants;

(d) Research Planning Grants (RPGs) and Career Advancement Awards (CAAs); and

(e) The Presidential Young Investigator Program

Luther S. Williams
Luther S. Williams

cc: Dr. Bernthal, O/D
Dr. White, O/DD

Telephone (202) 357-7557 FAX (202) 357-9813

[20] From: rbowen at nsf18 2/7/91 5:30PM (3689 bytes: 38 ln)
To: lwilliam at NOTE
cc: cbrownst at NOTE, dsanches at NOTE, kwillenb at NOTE, mclutter at NOTE,
  rcorell at nsf12
bcc: jawhite, rbowen, wmeier, skemnitz, pherer
Subject: Clarification?????
------------------------------ Message Contents ------------------------------

I need some clarification on a couple of issues which we discussed at the last EHR policy committee meeting.

The first issue concerns the amount of new money available in FY92 for FAW. Both Dave Sanches and I thought we heard you indicate that in FY92 you were requesting for EHR an additional $2.5M+ for FAW. This request, if funded, would yield $5M+ to support the "second fifty" FAWs from the FY91 solicitation and the second year of the "first fifty". During a conversation with some of the ENG staff concerned with FAW, one of them pointed out that the FY92 budget request for FAW only shows $2.65M. (See page EHR-26). Either Dave and I misunderstood, or you must have some other idea as to how to fund the second fifty. Please help us understand how the second fifty will be funded.

The sensitivity of the number and how they are funded is driven by my discomfort over the small allocation (5) from the first fifty which ENG is supposed to receive. If we should end up funding only fifty, then we must come to some agreement on a new distribution.

The second issue concerns the preliminary discussion we had about assigning certain EHR programs to the other Directorates. I indicated our interest in assuming responsibility for the MRI program. In taking this position, I assumed that MRI involved working with minority institutions rather than with minority investigators, regardless of institution. If the latter is the case, then I would like the opportunity to learn more about the responsibility before I commit our people. If the former is the case, then we are very much interested. Through an initiative started by John White last year, we have established relationships with the HBCU's which have Engineering programs. We would like the opportunity to enlarge these relationships with other minority institutions. I also understand that you have a Research for Minority Scholars program. We have an interest in this program should it be one which you put on your list for distribution.

If it works out that MRI is not the program for us, we do want to do our share by accepting other responsibilities. As would probably all directorates, we would enjoy having responsibility for the PYI program. Sharon Middledorf, of our EID Division, is expert on the current program and would be a reliable staff person to assign to this responsibility.

I hope you had a good EHR retreat. I will be out of town

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during the week of Feb 11. I will be reading my Email during part of the week should you want to answer this note.

Thanks

Ray

SCIENCE FOUNDATION
1800 G STREET, N.W.
WASHINGTON, D.C. 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR EDUCATION AND
HUMAN RESOURCES

February 19, 1991

MEMORANDUM

TO: Ray Bowen ✓
Charles Brownstein
Mary Clutter
Robert Corell
David Sanchez
Karl Willenbrock

FROM: Luther S. Williams Luther S. Williams

SUBJECT: Cross-Directorate Programs

At our most recent meeting, we (the EHR Policy Committee) decided that the following cross-directorate programs, for which the research directorates have management and fiscal responsibilities, would be transferred in full to the research directorates. Specifically, it is requested that the Acting Director approves the transfer of program coordination responsibility from the EHR Directorate to the research directorates as shown below.

(a) Research Experiences for Undergraduates (REU) - sites, MPS;

(b) Research in Undergraduate Institutions (RUI) - No assignment necessary;

(c) Minority Research Initiation (MRI) (Planning and regular) grants, ENG; and

(d) Research Planning Grants (RPGs) and Career Advancement Awards (CAAs), BBS

cc: Dr. Frederick Bernthal, O/D
Dr. John White, O/DD

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR ENGINEERING

February 25, 1991

MEMORANDUM

TO: Luther S. Williams
Assistant Director, EHR

FROM: Ray M. Bowen Ray M. Bowen
Acting Assistant Director, ENG

SUBJECT: Cross-Directorate Programs

The purpose of this memorandum is to alert you to a small point which was overlooked in your memorandum of February 19, 1991 to the members of the EHR Policy Committee. In an Email message to you dated February 7, 1991, I requested more information about the Minority Research Initiation (MRI) program prior to ENG assuming responsibility. I explained in that message we are interested in increasing our activities with minority institutions. If the program also involves the administration of awards to minority researchers regardless of their institutional affiliation, then we would like to learn more about the program prior to accepting responsibility. In the same Email message, I expressed an interest in ENG having a role with your Minority Scholars Program.

If you will identify a contact person within EHR for the MRI program, we will study this program further. Thank you for your attention to this request.

Copy furnished:
Dr. Frederick M. Bernthal
Dr. John A. White
Dr. Wilbur L. Meier, Jr.

Mr. WOLPE. I am raising this in part, because I am anxious to get a little clearer understanding about the decision-making process here. Just from an oversight standpoint, I would like to know how decisions get made. I think that would be useful for us to understand policy outcomes as well.

Before doing that, Dr. Sanchez, would you please stand?

[Witness sworn.]

Mr. WOLPE. You had wanted to make a comment, so please go ahead.

Dr. SANCHEZ. Mr. Chairman, thank you for allowing me to speak, and I want to thank the leaders and faculty of the four-year colleges who have played such an important role in bringing forth our country's future scientists.

I want to talk about commitment very briefly. The Mathematical and Physical Sciences Directorate, of which I am in charge, the MPS target for the four programs in question, RAW, MRI, RUI, REU, was $11.2 million. We awarded $12.9 million. That $1.7 million came out of our research base.

In 1991, for which we don't have the full figures, for instance the target within the RUI within our Directorate is $4.1 million. We have already obligated $6.4 million. Targeted funds are used for targeted programs and they are not moved back to the research base.

We use as much as possible the award figure of the previous year as the target for the next year. Hence, growth is built in, and it is demand-driven.

Talk about special responsibilities—research Directorates feel very strongly their key role in undergraduate education with the Federal EHR initiative. Let me give you a real simple example. Many of us have realized the paucity of upper division undergraduate courses in material science, one of the top priority sciences in the coming decade.

Within our 1993 budget request, I have assigned approximately $1 million to be used for developing such courses. I didn't ask Dr. Williams, I implemented the recommendation for the academic community, my own program officers.

Pride of ownership—what was described above was basically accomplished because of the pride of ownership of programs as Minority Research Initiation, Research Awards for Women, Research in Undergraduate Institutions, and Research Experience for Undergraduates, by the research Directorates, which knowing bureaucracies as you gentlemen do, would not occur, I believe, within a centralized management structure.

The advocacy of these programs by the research Directorates is a key factor in proposing commendable increases suggested by the Project Kaleidoscope report. I suggest, as Dr. Williams had alluded to, that most of the problems described in management can be solved by better informing program officers and better internal Directorate coordination and information dissemination.

Dr. Sullivan very aptly cited the very important synergy between the NSF program officer and the college professor which is what makes for real success. That's what I want to emphasize, that that occurs because we have a pride of ownership in the program, and we manage the program, and a large part of it comes out of our own research base.

Mr. **Wolpe**. Let me just say that I think the Project Kaleidoscope report, the witnesses' testimony today, and I might say, this committee historically, has really urged that the coordination and oversight responsibility for these undergraduate programs be housed, undertaken, by the Education and Human Resources Division.

I think the intent of this committee was certainly clear, and this change in policy by NSF, I certainly think, flies in the face of what had been the intent expressed by this committee.

In light of the history that we came upon in looking at RUI for this member highlighted the validity of the original concern and set of recommendations. I want to go to that at this point. My understanding is once this informal group had made its recommendation, that there was no—while the decision had been made to transfer responsibility out of the EHR, there was no final disposition of these programs actually included in the memorandum that was issued at that point.

In fact, according to the message that Dr. Bowen, a member of the EHR policy committee, sent to you, Dr. Williams, on February 7, I think you have the exhibit in front of you, according to this message the policy committee had preliminary discussions, not a decision, on these programs.

Was there a decision made at this policy committee meeting as far as you were concerned?

Dr. **Williams**. Yes. What is reflected in the first memo is what we decided. We basically went program by program and asked the following question. REU, as you know, is distributed to the research Directorates. It would be important to—I'm talking about two components of REU, to be precise. One is a supplement to a research grant, and that's not an issue.

Mr. **Wolpe**. Well, apparently not everyone at the meeting was aware that a decision was made, is that correct?

Dr. **Williams**. Yes, a decision was made.

Mr. **Wolpe**. But apparently not everyone was aware of the fact that a decision was made. Is that an accurate statement?

Dr. **Williams**. If you take literally Bowen's note to me, yes, that would be correct. We met and we made a decision. The decision is exactly what I have in my memo.

Mr. **Wolpe**. In a February 25 memo, Dr. Bowen again expresses concern about accepting one of these programs.

Dr. **Williams**. That's right.

Mr. **Wolpe**. This program was not transferred to Dr. Bowen's office as stated in the February 19 memo, is that correct?

Dr. **Williams**. That's correct, in response to that. That's the one that was retained in my Directorate, the Minority Research Initiation, and that's why it was retained.

Mr. **Wolpe**. And the RUI program, the memo says it has no assignment?

Dr. **Williams**. That's right. What I mean by assignment is that no one—we decided, as I indicated to you earlier, that we could manage without coordination. So no Directorate was assigned that coordinating responsibility. That's what it means.

What was being transferred is the coordination responsibility, everything else.

Mr. **Wolpe**. What comes across, though, is a judgment that the program was working well while it was being overseen by Education and Human Resources. So the policy committee decided to remove it from Education and Human Resources.

Dr. **Williams**. Remove the coordination, right. Well, the policy committee decided the coordination was not necessary. The merit of the decision is debatable. But that was the decision we made.

Mr. **Wolpe**. Well, I welcomed your indication of a reassessment. Because I think there is substantial——

Dr. **Williams**. Well, it's entirely reasonable. Let me make very clear and reiterate what I said earlier. It's true of RUI, and of all of our programs. The objective is to use a limited resource base to support a program designed by the very best advice we have to evaluate the program as it proceeds in order to ensure that it is as efficacious as possible. If one of the rate limiting events is that there is a problem in terms of coordination or related issues, then indeed we should reexamine it.

Mr. **Wolpe**. Let me just say that one element of this whole exercise that was a bit disturbing is that our staff had to discover this change in policy. When the decision to transfer programs was made, back in February, a lot of folks over at NSF had had the opportunity to share that decision with this committee and it was not done.

I would hope that in the future you could keep us informed and we could have a closer understanding of precisely what was contemplated and why, particularly in this instance where there is a violation of what had been established.

Dr. **Williams**. I will show you an instance of where an Education and Human Resource program will do just that.

Mr. **Wolpe**. I also think we do remain concerned about this and the other undergraduate programs that operate across the Directorates of the NSF. That's not to take away anything from the commitment of specific research Directorate heads, but it is to say that we want to be certain we don't lose focus, that the community of people that are so dependent on these feel that they have both an advocate, a mission and focused coordination.

Dr. **Williams**. I know it's difficult to convey what I am about to say in this setting. I am not concerned with that issue. It's possible that I could be concerned. The reason I am not concerned is the quality, the candor, of the interaction that I have with the policy committee and the assistant directors. There is no lack of consensus in terms of what we are attempting to accomplish and the willingness to operate in a collaborative mode.

Mr. **Wolpe**. Let me say I don't question your personal commitment.

Dr. **Williams**. It's not my personal——

Mr. **Wolpe**. Or that of other individuals that are involved here. But I don't want to see a situation that is dependent upon personal commitment. I would like to have an institutionalization of the process that can guarantee some continuity.

I must also go back to what I said in my opening statement. I have to tell you, the interaction that took place between the member of your Foundation, Mr.——

Dr. WILLIAMS. Yes. Mr. Danek.

Mr. WOLPE. Mr. Danek and my staff, it was frankly shabby. There should never have been that kind of conversation. And I was concerned about the nature of the interaction with my staff as to what it might say about the nature of the interaction between him and other staff. That kind of bureaucratic thing is not helpful. We are not here to do anything but try to help solve some problems and work with you to attain a solution to those problems.

So I hope that a message may be conveyed in the strongest possible way.

With that, Mr. Nagle.

Mr. NAGLE. Let me pursue the question that has been supplied to me by OTA. What would NSF say is the most constructive role Congress could play, aside from the provision of more funds?

Dr. WILLIAMS. I think we have in fact for several years—I will restrict my comments to the undergraduate arena—several years, almost now a decade, of growth in the budget. What that translates to is several years, five to seven years in some cases, of the program.

As has been indicated, the Foundation resource base is such that in trying to serve programs, undergraduate programs and research institutions, comprehensive institutions and the institutions represented by Project Kaleidoscope, it is very important that we have some reasonable sense of the difference that these programs are making. Because NSF's role is important but limited.

I would welcome the periodic queries from the Foundation with respect to what this growing enterprise is translating into, and what difference it is making.

I spoke earlier, and the other witnesses agree, that one of the most important things we have done, last year, was to start this attack on introductory courses, first-year courses. Several years out, we would like to know, are we occasioning the requisite change that we seek. So I don't know what the right words for that are, but something of that sort, beyond the important role in providing funds.

Mr. NAGLE. This is an aside, but I have to tell you that I was not terribly impressed with the commitment of the Administration. The President announced a new educational initiative this week, kind of taking a tin can, going around to the corporations and asking them to donate money.

It's kind of a national educational policy, a modern equivalent of the March of Dimes. Maybe we could do it in movie theaters during introductions, too. Why should just corporations be involved? That constitutes the national response to the crisis we have. I think we need much more leadership from the Administration in terms of support for funding and the challenge. And I found that disconcerting.

But the testimony we had today focused on the failures of our larger research institutions to effectively participate in undergraduate education. Is NSF looking at that at all in any direction or concept, or discussion? What's going on?

Dr. **Williams**. Yes, that's why I made the statement that the Project Kaleidoscope report, though a priority, is put in the context of other reports. We have actually looked at the issues. We have looked at another area of equal concerns, the two-year institutions, an issue where one cannot even begin to separate the broad issue that Dr. Cole was talking about with respect to minorities, because of the substantial enrollment.

There is a very real problem there. But I want to make quite clear what I think is NSF's role in dealing with the broad issue of research and education, as exemplified in research institutions. Certainly we can be helpful, catalytic, try and provide leadership and continue to raise the issue of achieving a more reasonable balance between teaching and education.

But ultimately, the driver for that disparate circumstance, as you heard this morning, is the value system of the university, the reward and value system, which I do not see as NSF's mandate. Nor if we were to incorrectly assume it, in my judgment, could we do very much about it.

Mr. **Nagle**. The thing that scares me about that is what I said earlier, and I don't necessarily disagree with all of what you said, but I am concerned that NSF has perceived its role as one of a stimulator and once it stimulates, it moves on. We don't have a continuity that is necessary to sustain programs.

Dr. **Williams**. That depends on the program.

Mr. **Wolpe**. I am a little disturbed by that. And I agree with the analysis of the value structure of the universities themselves being a principal determinant of the output.

But I disagree sharply with the suggestion that the Government and Government policy cannot play a role in helping to provide new direction if there is an area of major deficiency. And if in fact one of the things we are learning is that the educational base of science and math education, that is the teaching base, if you will, of science and math education, is so deficient, then it becomes to me pretty self-evident that one important role NSF can play is to put more resources into expanding its educational capacity than it has historically, that you shift the emphasis to deal with that particular deficiency.

Whereas, I think at least historically, the perception has been in the academic community that NSF gave grants for research, rather than grants for curriculum development, or grants to enhance educational teacher capacity. So I guess I am a little resistant to the way in which you have rejected the NSF's role there.

Dr. **Williams**. I'm sorry. I didn't categorically reject it. I tried to define its role. I fully agree with what you just described. But that is limited. The point I was making with respect to research universities, that is a fundamental issue, integral to the reward system of research-intensive universities.

Rather than taking that on per se, what NSF should do and what NSF is doing is exactly what you just described. It is providing increasing support to the undergraduate math and science and engineering component of those institutions.

But the question is often raised that if we could just reform—I spent nearly 20 odd years at universities before coming to NSF myself, most of which were research institutions. While the statement is often made that the NSF or the NIH grant is the driver, the fundamental issue is the definition of the professorate. If you are in a research-intensive university, primacy is assigned to a researcher scholarship. There is in my judgment no fundamental way NSF is going to do very much about that issue.

What we can do something about is precisely what you just stated. We can continue to make substantive investments in undergraduate education. At the margin, that will make some difference. But ultimately the larger issues stand.

Mr. **Wolpe**. I would argue that—I don't think we are quite saying the same thing. If in fact one of the major reasons we are not getting enough folks going into math and science generally and specifically, people from underrepresented groups, minorities and women, is because of the poor fashion in which science and math are taught, beginning in the K-12 and onwards into the undergraduate level of college, then I would think NSF ought to say that, very loudly, very dramatically, very clearly, that that is a major deficiency. You ought to be leading on that.

Dr. **Williams**. We do. We do say that.

Mr. **Wolpe**. I think to the extent that there is a much more focused—not looking at this as something you impact at the margin, but rather that a central mission of NSF ought to be to address this teaching, educational deficiency right now, it would be enormously helpful and ultimately impact upon the ethos and the understanding of these large institutions that now define themselves so heavily in research terms.

Mr. **Nagle**. If the gentleman will yield, I have been in this room for five years. I really hoped five years ago when I heard the kind of testimony that I heard this morning that five years later I would not have heard this kind of testimony I heard today. I have not seen a creative, energetic response from NSF to a continually growing crisis, other than continuing to try to stimulate.

I think you have to be more aggressive. I think you have to push much further, and I think you have to push for more of a continuum.

Dr. Williams, I would add in your defense you haven't been there, it's not your fault. Nevertheless, I read the Neal report when I first got here, and I read the PKAL report. I am somewhat astounded to see if there is a difference between the two. I know there are differences, but in essence the message is the same. We ain't getting the job done. The policy response of NSF seems to have been that we ain't going to get it done, that we can't do anything about it, that it's too bad. It's unfortunate, we will do what we can around the margins.

But we have wasted five years, and it appears to me if we continue with the same policies we are going to waste the next five, and I will be here 10 years from now and get the same kind of testimony again.

Dr. **Williams**. Maybe it's less than five. I would like to take a moment to tell you what we have done in the last year or so, that I think is different.

On the broad issue, Dr. Cole spoke about the broad issue of minorities, independent of institutions. We now have in place what I would call a comprehensive program that basically starts at middle school and ends with a doctorate degree, comprehensively addressing that problem, including within the undergraduate arena, a $10 million effort that only deals with minorities at the undergraduate level in science and engineering.

We have this undergraduate Course and Curriculum Development effort that is not a short-term model. We view this as a sustained effort that is going to take a considerable period of time to really reform undergraduate and freshman level courses. It was not designed as a model or an experiment.

We have initiated another program that focuses, a similar kind of effort, that focuses on women. Engineering curriculum, the undergraduate engineering curriculum has not really been comprehensively examined in 25 years. We have in place now the Engineering Directorate, several multi-million dollar coalitions that are going to run for a considerable period of time to completely revamp engineering education, which we cannot do without dealing with the pre-engineering courses that address it.

We are in the third year of a major program dealing with calculus, calculus in all institutional settings, liberal arts institutions, two-year institutions, research institutions, etc. So there has been, I would argue, a change in the focus of the Directorates programs, to what I would term more comprehensive, more reformed operations.

Mr. NAGLE. I thank the Chairman, and I thank you. It has been a very valuable hearing for me. I want to thank the other panelists that are still here. I have enjoyed it. I am somewhat saddened by it, but I do appreciate it. It is deja vu all over again.

Mr. WOLPE. Dave, I wonder if we might just ask OTA, as our last question, this will close out the hearing today, if you might—what's your reaction to NSF's progress to this point? The statement that has just been made, how would you respond in a critical way to the adequacy of NSF's response to this crisis?

Dr. CHUBIN. I guess I am now placed in a position of disagreeing with everybody.

Mr. NAGLE. You'd fit right in around here. [Laughter.]

Dr. CHUBIN. Right. OTA has been looking over NSF's shoulder for at least three or four years now, on science education matters, particularly at how education fits into the research mission of the Foundation. So I have several responses.

I think organizationally NSF is much better off now, since it reorganized into an Education and Human Resources Directorate, than it was before. I think it has gotten serious about undergraduate education. It took them a while, but they did, and I have told Luther this privately and publicly.

It is now starting to get serious about K-12. And I am convinced that the leadership understands that this notion of a system that is connected from maybe even pre-kindergarten through graduate school and into the early professional career is only going to be as strong as its weakest link. There need to be ways of making connections among these various stages of the system.

It is clear to OTA that NSF knows that. They have diagnosed that. And now the question is, how do they make some changes all along the pipeline? Particularly since they don't have the resources to do it adequately, in my view.

I now will part company with Dr. Williams a bit. I think it is not the role of the Federal Government to dictate what the reward structure should be on campus. That's what local educational leadership is all about. And we heard from many leaders today, and they are aware of what needs to happen.

Dr. **Williams**. Right, that's what I said.

Dr. **Chubin**. In this particular case, they are able to push the right buttons. However, that is not to say that NSF—and it's not just NSF as the FCCSET committee report makes it very clear that this is the responsibility of all the research agencies, all of whom have educational programs. It is going to take an effort that brings all those together, across all stages of the system.

I believe that NSF, like the other agencies, has programs for the very purpose of providing incentives to make people change their behaviors. If NSF wants to get universities to reward undergraduate teaching, they can find a way of doing it, I have confidence in them.

Mr. **Wolpe**. Thank you very much.

My ranking member, Mr. Boehlert, was unable to be here today, but has asked that his introductory statement be entered into the record. Without objection, it will be entered. I know that he shares many of the concerns we have discussed today, and I think he will be communicating directly with NSF, expressing those concerns.

[The prepared opening statement of Mr. Boehlert follows:]

SHERWOOD BOEHLERT
25TH DISTRICT, NEW YORK

COMMITTEES
SCIENCE, SPACE, AND TECHNOLOGY
VICE CHAIRMAN, SUBCOMMITTEE ON
INVESTIGATIONS AND OVERSIGHT
PUBLIC WORKS AND TRANSPORTATION
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TRADITIONAL AND NON-TRADITIONAL SOURCES OF FUTURE RESEARCH SCIENTISTS

STATEMENT BY THE HONORABLE SHERWOOD BOEHLERT (R-NY)

JULY 11, 1991

I want to thank you, Mr. Chairman, for calling this hearing on undergraduate science education. I also want to welcome our distinguished witnesses and thank them for the excellent written testimony they have submitted.

This is not the first hearing on science education, nor will it be the last, but this hearing, building on the efforts of the Kaleidoscope Project's report, focuses our attention on important and often underrepresented elements of our nation's undergraduate science enterprise. Small colleges--liberal arts colleges, historically black colleges and universities, women's colleges--have an outstanding record of success in science and math education. This success can be measured in terms of the number of science majors who leave these schools and go on to graduate work in the sciences. It is also evident in the large, if unquantifiable,number of students who graduate from these schools with no intention of being professional scientists, but they leave their undergraduate institution as citizens literate in the sciences, able to face the challenges of our technologically complex world.

The witnesses appearing before us today will help highlight what these schools do well--often better than any other institutions--what others may learn from their success, and also how these schools may do even better in the future.

The Federal government has an important role to play in setting out incentives that reward professors for actively engaging in both teaching and research scholarship. I look forward to hearing from Dr. Daryl Chubin of the Office of Technology Assessment and Dr. Luther Williams of the National Science Foundation on what the Federal government, most specifically NSF, can do to help create and reinforce these incentives in the effort to build science communities.

THIS STATIONERY PRINTED ON PAPER MADE OF RECYCLED FIBERS

Mr. **Wolpe**. Let me express my appreciation to both Dr. Chubin and Dr. Williams for your testimony today and for your assistance to this committee.

Thank you very much. The hearing stands adjourned.

[Whereupon, at 1:09 p.m., the subcommittee adjourned, to reconvene at the call of the Chair.]

APPENDIXES

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

nsf
OFFICE OF THE DIRECTOR

July 12, 1991

The Honorable Howard Wolpe
House of Representatives
1421 Longworth House Office Bldg.
Washington, D.C. 20515

Dear Mr. Wolpe:

I have become aware of your comments at yesterday's hearing before the Subcommittee on Investigations and Oversight regarding the poor impression conveyed to you and your staff by inquiries from my staff.

First, let me assure you I appreciate and share your strong support for undergraduate research and education programs, including the Research in Undergraduate Institutions program. I regret that there has been confusion regarding Foundation management of the program. This program is supported across NSF by our research directorates and enjoys significant success and popularity.

It is my immediate intention to review thoroughly how well we are managing the program and responding to the external community who want information about it. Where we find deficiencies we will make corrections. I will keep you informed about results and would be glad to discuss this personally with you and other interested committee members at your convenience.

I also am taking several steps to sensitize my staff to their responsibilities regarding complete and open responsiveness to Congressional and to public requirements for information.

Your support for the National Science Foundation is deeply appreciated.

Sincerely,

Walter E Massey

Walter E. Massey
Director

SEP 1 6 REC'D

NATIONAL SCIENCE FOUNDATION
1800 G STREET, N.W.
WASHINGTON, D.C. 20550

September 13, 1991

OFFICE OF THE
ASSISTANT DIRECTOR
FOR EDUCATION AND
HUMAN RESOURCES

Honorable Howard Wolpe
Chairman, Subcommittee on
Investigations and Oversight
Committee on Science, Space, and
Technology
U. S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

I am enclosing answers to your questions posed August 9, 1991, as a result of the Subcommittee hearing of July 11, 1991, on "Traditional and Nontraditional Sources of Future Research Scientists".

As you know, the Director of the National Science Foundation has vested coordination and management of the cross-directorate activites at NSF in the Directorate for Education and Human Resources. Accordingly, I have revised the duties of Dr. Peter Yankwich, who has functioned as the Directorate's Executive Officer, permitting him to assume overall information and coordination responsibility for all the referenced cross-directorate programs. I will soon inform our external communities of these actions.

Sincerely,

Luther S. Williams
Luther S. Williams
Assistant Director

Enclosure

Telephone (202) 357-7557 FAX (202) 357-9813

QUESTIONS SUBMITTED FOR THE RECORD BY THE HONORABLE HOWARD WOLPE

1. **Please provide the budget targets and actual (or estimated) expenditures for the Research in Undergraduate Institutions (RUI), Research Experiences for Undergraduates (REU), Minority Research Initiation (MRI) and Faculty Awards for Women (FAW) programs within each NSF Directorate for the Fiscal Years 1989-90, 1990-91, 1991-92.**

   The attached table (ATTACHMENT A) provides information on budget targets and actuals for the requested programs for FY 1989-FY 1991. Only targets are provided for FY 1991 as the year is not yet complete. From preliminary data it appears that all targets will be met or exceeded as in the previous two fiscal years. While a target is listed for FAW, it should be pointed out that FAW is a line item in the EHR budget unlike the other programs included here. Therefore, the actual will be the same as the target.

   Please provide the projected budget targets within each NSF Directorate for the above programs for FY 1992-93.

   Targets for FY 1992 will not be set until Congressional action on the FY 1992 budget is complete. The targets are established each year when the Current Plan for the year is developed.

2. **Please provide a summary of the decision-making process which led earlier this year to the decision to remove coordination of the REU and RUI programs from the Education and Human Resources (EHR) Directorate. Please cover the following points in your response:**

   a. **Date of and reason for the decision.**

      Date: December 26, 1990 and subsequent senior staff meetings with the Acting Director and Acting Deputy Director.

      Reason: Management and fiscal responsibility for REU and RUI were (and are) vested in the disciplinary directorates: BBS, CISE, ENG, GEO, and MPS. Proposals are directed to the disciplinary programs within these directorates, the review of them is implemented there, and award/decline decisions are made there.

   b. **Documentation of the decision-making process. Please attach all documents relating to and documenting this decision, including minutes, letters, memos, electronic mail, notes, telephone logs and other records of oral communications.**

As stated above, at its December 18, 1990 meeting the EHR Policy Committee decided to recommend that several cross-directorate activities for which EHR had no fiscal or management responsibility should be coordinated in the research directorates. This preliminary decision was communicated to the Acting Director and Acting Deputy Director via memo (ATTACHMENT B) of December 26, 1990 recommending approval by the Acting Director.

Subsequent to December 26 (see e-mail of 2/7/91 (ATTACHMENT C) and memo of 2/25/91 (ATTACHMENT D)), Dr. Ray Bowen, ENG, states that he considers the decisions to be preliminary and raises the possibility that ENG may not wish to assume responsibility for MRI.

MPS moved immediately to begin coordination of REU including preparation of new guidelines. BBS initiated discussions relating to the issues involved in coordinating the Career Advancement Awards and Research Planning Grants for Women.

No written directive was issued by the Acting Director with regard to the recommendations of December 26, 1990, but the issues were discussed and decided in subsequent senior staff meetings.

c. **List names and positions of all persons involved in the decision-making process and their roles. Specify by name and position the final decision-maker(s).**

Members of the EHR Policy Committee:

Dr. Luther S. Williams, Chair--AD/EHR
Dr. Mary E. Clutter--AD/BBS
Dr. Charles Brownstein--Acting AD/CISE
Dr. Ray Bowen--Acting AD/ENG
Dr. Robert Corell--AD/GEO
Dr. David Sanchez--AD/MPS
Dr. Karl Willenbrock--AD/STIA

Office of the Director: Dr. John White, Acting Deputy Director
Dr. James Hays, Senior Science Advisor

Decision-Maker: Dr. Frederick M. Bernthal
Acting Director, NSF

d. **The process by which NSF offices and outside parties were notified of the decision. Please attach all documents, including minutes, letters, memos, electronic mail, notes, telephone logs and other records of oral**

communications, relating to the notification of both NSF offices and outside parties of the decision.

The decision to transfer coordination of the cross-directorate programs discussed herein to the disciplinary research directorates was informally communicated to NSF program staff. No formal notification was made to outside parties pending review of effectiveness of implementation.

3. **Is there a consistent, decision-making process in place at the NSF for issues related to the structure, organization and conduct of the above programs and other like programs at NSF? Please provide any documents describing the decision-making process and discuss in full the decision-making process, including the following points:**

a. **Selection of "decision-makers"**

The new Director of the National Science Foundation has recently established a Director's Policy Group (ATTACHMENT E) whose membership is made up of the Assistant Directors, the Controller, and the Head of the Office of Legislative and Public Affairs. This group is the forum for discussion of issues such as coordination of cross-directorate programs. Preliminary decisions of this group are normally discussed before formal issuance with the Executive Council. The Executive Council is chaired by the Deputy Director and its members include the AD's, Deputy Assistant Directors, and Heads of Staff Offices.

b. **Documentation of decision-making process**

O/D establishing the Director's Policy Group and revised Executive Council is attached.

c. **Chain of approval for proposals for changes in existing procedures**

Suggested changes to existing procedures can originate anywhere in the Foundation. They would usually be brought to the Director's Policy Group through an Assistant Director. Any formal proposed decision of record is normally reviewed by the Assistant to the Director and the Deputy Director before signature by the Director.

d. **Method of notification of outside parties and Congress of any changes made.**

Normal procedure for notification of outside parties would include as appropriate: an Important Notice to

Presidents of Institutions, an item in the NSF Bulletin, inclusion in the annual Guide to Programs, items in professional society publications, discussion at public meetings. Congressional notification would normally be accomplished by formal letters and briefings to the authorization and appropriations committees, along with day-to-day liaison at the staff level.

4. **Please provide the name, position, office and specific duties of all individuals (excluding support staff) currently involved with coordination, contact with the public, and preparation of announcements, evaluation and recommendations for the REU, RUI, MRI and FAW programs.**

REU: Dr. Deborah Lockhart, Coordinator
Staff Associate, AD/MPS

From February to August 1991, Dr. Lockhart provided a single point of contact for questions from the research community (and others) about the REU program, including application procedures, deadlines, and specific disciplinary contacts in Divisions. She coordinated the review of new guidelines, including arranging for printing and distribution. She has also prepared an annual informational listing of funded projects for public distribution. From August to the present Dr. James Wright assumed these responsibilities.

RUI: None. From February 1991 to the present research directorates assumed responsibility for coordination of this activity.

MRI: None. From February 1991 to the present research directorates assumed responsibility for coodination of this activity.

FAW: Dr. Sonia Ortega
Associate Program Director
Division of Human Resource Development, EHR

Dr. Ortega serves as the program officer with full responsibility for the FAW program. She has a Foundation-wide advisory committee comprised of program officers from all of the disciplinary research divisions. With the assistance of this committee, she developed review procedures, established panels, coordinated award/decline recommendations with research programs, developed materials for communicating with awardees, and has set in place procedures for monitoring awards and revising guidelines for future competitions.

The situation described above will change during September 1991 when a full-time Senior Staff Associate for Coordination of Cross-Directorate Programs will be appointed within the Directorate for Education and Human Resources. Overall coordination, contact with the public, preparation of announcements, preparation of special reports, recommendations for program evaluation and program revision will all be vested in this position.

ATTACHMENT A

CROSS DIRECTORATE PROGRAMS -- FY 1989 - FY1991

	BBS	CISE	ENG	GEO	MPS	STIA	EHR	NSF TOTAL
REU								
1989 Target	3.100	1.776	1.950	2.200	2.974			12.000
1989 Actual	3.649	1.696	2.766	1.548	4.135	0.249		14.043
1990 Target	3.600	1.776	3.000	1.700	4.100			14.176
1990 Actual	4.105	1.721	3.290	1.572	5.158	0.295		16.141
1991 Target	4.000	1.776	3.300	1.700	4.100			14.876
RUI								
1989 Target	4.100	0.824	0.850	1.500	2.726			10.000
1989 Actual	8.989	0.898	1.158	2.410	5.211	0.049		18.715
1990 Target	5.000	1.190	1.000	2.500	5.200			14.890
1990 Actual	9.129	1.277	0.884	3.365	5.615	0.002		20.272
1991 Target	5.000	0.825	1.000	2.500	5.200			14.525
MRI								
1989 Target	1.200	0.260	0.280	0.260	1.100			3.100
1989 Actual	1.856	0.939	0.845	0.112	1.090	0.080		4.922
1990 Target	1.350	0.300	0.330	0.260	1.160			3.400
1990 Actual	1.981	0.240	1.010	0.268	1.448			4.946
1991 Target	1.400	0.335	0.330	0.295	1.285			3.645
FAW								
1991 Target							2.500	2.500

1800 G STREET, N.W.
WASHINGTON, D.C. 20550

ATTACHMENT B

OFFICE OF THE
ASSISTANT DIRECTOR
FOR EDUCATION AND
HUMAN RESOURCES

December 26, 1990

MEMORANDUM

TO: Raymond Bowen
Charles Brownstein
Mary Clutter
Robert Corell
David Sanchez
Karl Willenbrock

FROM: Luther S. Williams

SUBJECT: Cross-Directorate Programs

At our December 18th meeting, we (the EHR Policy Committee) decided that the following cross-directorate programs, for which the research directorates have management and fiscal responsibilities, would be transferred in full to the research directorates. Thus, this memorandum is to reiterate that decision and to recommend to the Acting Director approval of the transfer of program coordination responsibility from the EHR Directorate to the research directorates for:

(a) Research Experiences for Undergraduates (REU) - (already accomplished);

(b) Research in Undergraduate Institutions (RUI);

(c) Minority Research Initiation (MRI) (Planning and regular) grants;

(d) Research Planning Grants (RPGs) and Career Advancement Awards (CAAs); and

(e) The Presidential Young Investigator Program

Luther S. Williams
Luther S. Williams

cc: Dr. Bernthal, O/D
Dr. White, O/DD

Telephone (202) 357-7557 FAX (202) 357-0615

ATTACHMENT C

(30) From: rbowen at nsf18 2/7/91 5:30PM (3689 bytes: 58 ln)
To: lwilliam at NOTE
cc: cbrownat at NOTE, dsanches at NOTE, kwillenb at NOTE, mclutter at NOTE,
  rcorell at nsf12
bcc: jawhite, rbowen, wmsler, shamnitz, pherer
Subject: Clarification?????
------------------------------- Message Contents ------------------------------
---

I need some clarification on a couple of issues which we discussed at the last EHR policy committee meeting.

The first issue concerns the amount of new money available in FY92 for FAW. Both Dave Sanches and I thought we heard you indicate that in FY92 you were requesting for EHR an additional $2.5M+ for FAW. This request, if funded, would yield $5M+ to support the "second fifty" FAWs from the FY91 solicitation and the second year of the "first fifty". During a conversation with some of the ENG staff concerned with FAW, one of them pointed out that the FY92 budget request for FAW only shows $2.65M. (See page EHR-26). Either Dave and I misunderstood, or you must have some other idea as to how to fund the second fifty. Please help us understand how the second fifty will be funded.

The sensitivity of the number and how they are funded is driven by my discomfort over the small allocation (5) from the first fifty which ENG is supposed to receive. If we should end up funding only fifty, then we must come to some agreement on a new distribution.

The second issue concerns the preliminary discussion we had about assigning certain EHR programs to the other Directorates. I indicated our interest in assuming responsibilty for the MRI program. In taking this position, I assumed that MRI involved working with minority institutions rather than with minority investigators, regardless of institution. If the latter is the case, then I would like the opportunity to learn more about the responsibility before I commit our people. If the former is the case, then we are very much interested. Through an initiative started by John White last year, we have established relationships with the HBCU's which have Engineering programs. We would like the opportunity to enlarge these relationships with other minority institutions. I also understand that you have a Research for Minority Scholars program. We have an interest in this program should it be one which you put on your list for distribution.

If it works out that MRI is not the program for us, we do want to do our share by accepting other responsibilities. As would probably all directorates, we would enjoy having responsibility for the PYI program. Sharon Middledorf, of our EID Division, is expert on the current program and would be a reliable staff person to assign to this responsibility.

I hope you had a good EHR retreat. I will be out of town during the week of Feb 11. I will be reading my Email during part of the week should you want to answer this note.

Thanks

Ray

WASHINGTON DC 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR ENGINEERING

ATTACHMENT D

February 25, 1991

MEMORANDUM

TO: Luther S. Williams
Assistant Director, EHR

FROM: Ray M. Bowen Ray M. Bowen
Acting Assistant Director, ENG

SUBJECT: Cross-Directorate Programs

The purpose of this memorandum is to alert you to a small point which was overlooked in your memorandum of February 19, 1991 to the members of the EHR Policy Committee. In an Email message to you dated February 7, 1991, I requested more information about the Minority Research Initiation (MRI) program prior to ENG assuming responsibility. I explained in that message we are interested in increasing our activities with minority institutions. If the program also involves the administration of awards to minority researchers regardless of their institutional affiliation, then we would like to learn more about the program prior to accepting responsibility. In the same Email message, I expressed an interest in ENG having a role with your Minority Scholars Program.

If you will identify a contact person within EHR for the MRI program, we will study this program further. Thank you for your attention to this request.

Copy furnished:
Dr. Frederick M. Bernthal
Dr. John A. White
Dr. Wilbur L. Meier, Jr.

ATTACHMENT E

NATIONAL SCIENCE FOUNDATION
OFFICE OF THE DIRECTOR
WASHINGTON, D.C. 20550

STAFF MEMORANDUM

O/D 91-12
May 2, 1991

ADMINISTRATION AND MANAGEMENT

SUBJECT: Director's Policy Group

Since assuming the Directorship of the National Science Foundation last month I have recognized the need for a new senior consultative group in addition to the Foundation's existing Executive Council. The new group--to be called the Director's Policy Group (DPG)--will consist of the Foundation's Assistant Directors plus the Directors of the Office of Budget and Control (OBAC) and the Office of Legislative and Public Affairs (OLPA). I expect to meet with this group weekly to seek their advice and assistance on a wide range of policy matters.

Executive Council, consisting of the Assistant Directors or their designees and the Directors of all staff offices within the Office of the Director, will serve as a forum for consultation and communication within the Foundation. One of its principal purposes will be to insure that proposed changes to policies and practices are adequately discussed by appropriate Foundation staff prior to implementation. Executive Council will continue to review all task force and committee reports, and will coordinate executive activities such as budget planning and quarterly reviews. Dr. Bernthal will chair the Executive Council.

Walter E. Massey

Walter E. Massey
Director

Distribution: All Employees

○